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Progress Report on Estimating Density and Abundance of Marine Turtles: Results of First Year Pelagic Surveys in the Southeast U.S.

By

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Executive Summary

- Seasonal aerial pelagic surveys for marine turtles from Cape Hatteras, N.C. to Key West, Florida out to the western boundary of the Gulf Stream.

- Because the aircraft allowed for direct observation of the transect line transect methods of analysis were used in density estimation of <u>Caretta caretta</u>.

- <u>Caretta</u> <u>caretta</u> were sighted primarily during the spring and summer surveys and non-randomly distributed throughout the study area with statistically significant aggregations off Cape Canaveral, Florida.

- Minimum numerical estimates (N) are by season, with standard error of N:

	N	SE
spring	18,996	1,187
summer	14,932	477
fall	6,164	671
winter	4,877	3,268

- The precision associated with seasonal numerical estimates are 6.3%, 3.1%, 10.9% and 6.7% respectively.

Introduction

The Endangered Species Act of 1973 directs the National Marine Fisheries Service (NMFS) to protect and conserve all species marine turtles occuring in U.S. jurisdictional waters. To this end, the NMFS must assess the status of marine turtle stock(s) and monitor that status. This requires estimates of numbers of turtles by species and abundance and distributional trends for determination of that status of stocks in relation to past and future human activities. A three-year aerial survey research program was initiated by the Southeast Fisheries Center (SEFC) in the southeast United States in April 1982 to provide these estimates. This report gives the progress and results of the first year of this effort and the recommendations for improving the experimental design in subsequent years.

Numerical estimates for sea turtles have been determined only for nesting (i.e. mature) females which can be counted (or their nests) on nesting beaches. The majority of turtles however are pelagic and are never encountered alive on land. One way to collect data on pelagic animals is to survey the pelagic environment with an airplane. The SEFC has pursued this approach to collect data on pelagic turtles with the purpose of 1) defining distributions within the study area, 2) determining what environmental and behavioral factors effect turtle sightability, 3) estimating turtle density and abundance by species to be used in projection population models and 4) determining the utility of pelagic surveys to describe distributions and estimate abundance.

Pelagic surveys were conducted from Cape Hatteras, NC to Key West, FL, out to the western boundary of the Gulf Stream on a seasonal basis. The spring survey was conducted in April/May, 1982; the summer survey in July/August, 1982; the fall survey in October/November, 1982; and the winter survey in January/February, 1983. This study area represents a southern extension of aerial surveys (called CETAP) conducted by the University of Rhode Island, under contract with the Bureau of Land Management from 1979-1981. While the CETAP data are not comparable to those of the SEFC, they provide information on turtles north of the area of responsibility of the SEFC. The CETAP surveys and those of Fritts and Reynolds (1981) in the Gulf of Mexico were multispecies surveys which included marine turtles with marine mammals and birds. The SEFC/NMFS surveys are the first large scale pelagic surveys designed and flown specifically for collecting data on marine turtles.

These SEFC surveys provide the first comprehensive information on the distribution and abundance of marine turtles in the pelagic environment. The first year surveys provide baseline data on which the second and third year surveys were designed and stratified. In addition to completing seasonal surveys in the second year, a special experimental survey was completed (June, 1983) with the purpose of providing data with which to statistically evaluate the potential effect of Beaufort sea state on the ability of the observers to sight turtles and the potential effect that diurnal surfacing behavior of turtles may have on the numbers of turtles observed. It is anticipated that in the third year an experiment will be completed to determine the sizes of turtles observed at our survey altitude. This report addresses only the results of the first year pelagic survey. These surveys were designed to provide annual and seasonal comparisons and subsequent reports will include additional survey years as they are completed.

Methods

Survey Methods

Surveys were designed so line transect methods of density estimation could be applied. Surveys were flown in a Beechcraft AT-11 (aircraft number N500, N900) equipped with a plexiglass and glass bubble nose which offers a direct and unobstructed view of the line of flight. The observation bubble was calibrated and marked in 1/16 nm perpendicular distance intervals out to 5/16 nm from the trackline. This facilitated reporting of sightings with right angle distance from the trackline and allows for the application of line transect methods to estimate density (Burnham, Anderson and Laake, 1980). A more detailed description of the survey methods used is provided in Thompson and Shoop (1983).

Four aerial observers were included on all flights. Observers usually rotated through the bubble nose at the end of each transect. The total time a given observer was in the bubble nose within a flight day was no more than 1½ hours per observation period and 5 hours per survey day. One of the observers not "on watch" (in the observation bubble) was the data recorder while the other rested. During the summer survey a Hewlett-Packard 85 microprocessor with an internal clock was installed on the aircraft. This was used on all subsequent surveys to record data. In addition to allowing direct keypunching of all sighting data and transect information with time onto digital tapes, it directly interfaced with the radiometer and Loran C for automatic recording of sea surface temperatures and position as latitude and longitude.

The total study area is approximately 30,000 nm^2 and was subdivided into ten sampling areas or blocks of nearly equal area (±3000 nm^2) (Figure 1). Transects were selected randomly from the total potential transect lines placed 1 nm apart in a northwest to southeast orientation. This direction was selected because it maximizes coverage over depth strata while minimizing the effects of sun glare. The transects flown were randomly selected using a random number table and a random number generator available on the NMFS/SEFC Burrough's computer.

The total number of transects flown in each block for each survey is presented in Table 1. These are the transects with data that were utilized in the subsequent analyses. The primary criterion utilized in determining whether a block or transect was sampled adequately (called "made good") was the Beaufort sea state encountered. Sea states of 4 or less were considered appropriate for sighting turtles. Thus, for a block to be considered sampled at least 67% of the total trackline flown must have been of sea states 4 or less or considered "made good". About 700 lineal nm were flown each survey day (i.e., one block was completed each day). Thus, at least 469 nm had sea states of 4 or less on any given survey day (i.e., "made good"), to be included in these analyses.

An empirically derived effective swath width (w) of .334 nm was suggested by the contractor and used in predetermining the level of sampling effort. Utilizing this value and 700 nm of transect line results in an approximate sampling level of 8% in each block and thus, the study area. This 8% value is derived as:

$$(700 \text{ nm})(.334 \text{ nm}) = 233.8 \text{ nm}^2 \text{ sampled}$$

$$233.8 \text{ nm}^2/3000 \text{ nm}^2 \text{ per block} = 0.079 = 8\%$$

The actual sampling effort realized was calculated for each survey using the resulting value of w for each seasonal survey.

Transects were flown sequentially from north to south or vice versa. During each survey, an established recording and observation protocol was followed. The information recorded is presented in Figure 2. Included as the minimal information for each turtle sighting was: sighting interval (in 1/16 nm increments), reliabililty of species identification (sure, probable, possible), and observer.

Analytical Methods

General Approach

The ultimate objective of these surveys is to determine the seasonal abundance of turtles by species within this study area. Numerical abundance is estimated as:

$$\hat{N} = A \cdot \hat{D}$$

$\hat{N}$ = abundance estimate

A = total area of study area

$\hat{D}$ = estimated turtle density

To estimate abundance, an estimate for turtle density ($\hat{D}$) must be derived. Utilizing line transect methods, the generalized formula for density estimation is:

$$\hat{D} = \frac{n\hat{f}(0)}{2L}$$

$\hat{D}$ = density estimate

n = number of animals sighted

$\hat{f}(0)$ = intercept of probability density function (pdf)

L = total line length "made good"

This method of density estimation is considered in detail in later portions of this report. However, this formula reveals the parameters necessary for density estimation: n, $\hat{f}(0)$ and L. Therefore, environmental factors and turtle behavior which impact these components (n, $\hat{f}(0)$ and L) will impact the estimate of turtle density ($\hat{D}$). Potential impacting factors include:

1. The actual distribution of animals within the study area. Line transect methods assume that animals are randomly distributed along transect lines and within sampling blocks. Significant derivations from randomness effect the variance of n and D, thus it is important to define the actual distributions of turtles statistically. In addition, the actual causes of these distributions must be elucidated to determine if stratification of sampling effort is required in the following survey years to provide greater precision of all estimated parameters.

2. Increasing sun glare and Beaufort sea state and decreasing water clarity may potentially reduce the ability of observers to sight animals, and result in an underestimation of density by underestimating n and $\hat{f}(0)$.

3. Diurnal surfacing behavior of turtles, if significant will reduce sample sizes (n).

4. Unless corrected for time at the surface, all density and abundance estimates are for animals at the surface.

Each of these is considered analytically in detail and in the above sequence to provide density and abundance estimates with minimum bias.

Distributional Analysis

All species sightings are accompanied by an index of reliability. Reliability refers specificially to the observers ability to identify a turtle to species level. Observers identify turtle species as "positive, probable or unsure" and only turtles positively identified to species level were used in all analyses. The resulting proportions of turtles positively identified to any of the five species might be used to upwardly adjust species counts by incorporating turtles not identifed to species level (i.e., termed "unknowns"). However, this approach was not used at this time because of the unknown magnitude potential bias which might be introduced, but cannot be measured.

An assumption of line transect methods is that animals are randomly distributed along transect lines. Failure to meet this assumption will result in biased estimates of variance in density ($\hat{D}$) and sampling sizes (n), unless the underlying statistical distribution is accommodated. To test this assumption, the distance between _C. caretta_ was used as a measure of aggregation (Pielou, 1978). When 5 or more _C. caretta_ were observed along transects, a mean distance _between_ animals and a variance were computed.

When the variance (v) is equal to the mean (m) defined as: $I = v/m = 1$, where I is the Index of Dispersion, the spatial pattern is considered random and the statistical distribution is a Poisson (Pielou, 1977). As the value of this index (I) increases, the degree of spatial clumping is more apparent. As the value of I decreases relative to 1, the amount of clumping decreases as spatial uniformity increases. The null hypothesis is that turtles were randomly distributed along transect lines, and under this hypothesis, I has an approximate X^2 distribution with n-1 degrees of freedom which allows for significance testing (Perry and Mead, 1979).

This Index of Dispersion ($I = v/m$) was also used to compare the spatial distributions of _C. caretta_ between blocks within each season or within the study area. Because the blocks are approximately equal in area, they are treated as sampling quadrats. A mean and variance using the frequency per block for 10 blocks was computed for each season. A value of I was computed for each season and compared to unity by using the X^2 approximation (Seber 1982). The frequencies of C. caretta and D. coriacea were cross-classified by survey (or season) and block. These frequencies were also examined using the Index of Dispersion to evaluate the spatial distributions of these species between blocks on a seasonal basis.

While spatial distributions are described using this index of dispersion (I), the mechanisms underlying these spatial patterns are not defined. Those factors effecting distribution will be used in subsequent survey years to appropriately allocate sampling effort. That is, once it is discerned where turtles are, sampling can be stratified to improve the precision of resulting estimate and minimize bias. A canonical correlation analysis was used to define the distributional mechanisms of turtles. The absolute frequencies of turtles by species were classified by depth in fathoms, sea surface temperature and the presence of other species. Depth, temperature and other species presence were used as the independent variables in this analysis because they were measured and available in the data base. This multivariate technique was used to describe the potential linear relationships between the occurrence or frequency of turtles classified as C. caretta, D. coriacea, and unidentified to species level, (the dependent variables), and the three measured environmental correlates, depth, sea surface temperature, and animal associations as applied in Pielou (1977) and Morrison (1976). There may be other environmental factors which effect turtle distributions such as food availability, breeding activities, or temperature below the surface. However, only depth, sea surface temperature and the presence and abundance of other species were measured and used in this analysis. Because the analysis was not used to quantify potential linear relationships by creating new independent variables, deviations from linearity were ignored (J. Zwiefel pers. comm.). The linear model used in this analysis is that of Morrison (1976). In addition, the frequency of sightings of C. caretta and D. coriacea relative to total effort over depth and temperature strata were evaluated to examine the potential effects of these variables on turtle distributions.

Sightabililty

Sightability refers to the observer's ability to sight and correctly identify a turtle to species level. Factors affecting sightability include glare amount, Beaufort sea state and clarity of the water. Compounding these factors are the potential effects of season and location or sampling block. To evaluate the potential effect of these five factors, each C. caretta sighting was cross classified by survey number (season), sampling block, glare amount, sea state and water clarity. Numerical indices for glare amount were from 1 (none) to 4 (severe), for sea state from 0 (flat) to 4 (considered maximum acceptable for survey purposes) and for water clarity from 1 (clear) to 3 (turbid). With the four surveys and ten sampling blocks, this crossclassification scheme yields a five dimension table with 4x10x4x5x3 = 2400 cells. A Chi-square multidimensional contingency analysis was performed using these data to determine the effect of these factors on the frequencies of turtle sightings. The null hypothesis for this analysis is that these factors do not effect sightability and all cell frequencies are equal. This analysis applies the log-linear model to fit the data hierarchically as in Fienberg (1977).

The model used is (Feinberg, 1977):

$$e_{i,j,k,l,m} = \left\{ \prod \frac{(n_{i,j,k,l,m})}{N} \right\}^{N}$$

which is linearized to:

$$\ln e_{i,j,k,l,m} = \left\{ \sum \frac{(n_{i,j,k,l,m})}{N} \right\} - \ln N$$

where

e,i,j,k,l,m = expected cell frequency of C. caretta by survey block, glare amount, sea state, water clarity.

$n_{i,j,k,l,m}$ = observed frequency by survey, block, glare, sea state, water clarity.

N = total frequency.

The Pearson goodness-of-fit Chi-square statistic was computed after Feinburg (1977) for each potential model with the null hypothesis of equality of cell frequencies.

To further determine the effect of sea state, glare and water clarity on sightings, these frequencies of C. caretta were apportioned by sea state, glare amount and water clarity, and the total lineal miles flown were also apportioned by sea state, glare and water clarity. The potential linear dependence of C. caretta sightings on sea state, glare and water clarity was examined using a Spearman rank correlation analysis with the proportion of C. caretta sightings as dependent on sea state, glare amount and water clarity.

In this way, sighting frequencies were compared to the actual effort realized for sea state, glare amount and water clarity.

The above analyses specifically examine the potential effects of variation in specific environmental factors or turtle sightability and distributions. The potential diurnal behavior of turtles was also examined relative to sightability. A "time-of-day" effect was investigated as in Thompson and Shoop (1981). The absolute frequency of sightings for hourly intervals by season from 0900 to 1400 hours were compared using a Chi-square test (Snedecor and Cochran, 1967). These intervals were used because effort was approximately equal over these hours for each seasonal survey, and survey day.

Numerical Abundance

These pelagic aerial surveys were primarily designed to provide seasonal estimates of turtle density by species. Only sightings accompanied with a reliability index value of 3 (3 = sure) were used in final density estimates. Density estimates were derived using line transect methods as described in detail by Burnham, Anderson, and Laake (1980). Because the aircraft allows direct viewing of the transect line, all density estimates are of the form:

$$\hat{D} = \frac{n\hat{f}(0)}{2L}$$

$\hat{D}$ = turtles/nm^2

n = number of turtles sighted by species on transect

$\hat{f}(0)$ = intercept of probability density function

L = total transect line length "made good".

A probability detection function (pdf) was derived for each season using data pooled over all blocks to optimize sample sizes. The probability detection function selected was based on the criteria established as follows by Burham, Anderson, and Laake (1980). A sightabililty or detection curve was used for each survey to derive the pdf and each sightabililty curve was organized in 1/16 nm intervals from the transect line (zero) out to 5/16 nm. This interval distance was consistent with the actual interval marks on the AT-11 observation bubble. Various models were alternatively fit to the detection curve and by applying the selection criteria of Burham et al (1980) one model was chosen as the best pdf. The models available on the computer program TRANSECT were used in curve fitting were: Fourier Series (FS), negative exponential (NEG EXP), exponential power series (EXP), non linear polynonial (POLY), and the half-normal (HALF). The intercept of the selected pdf gives the value of f(0) used in density estimation.

A seasonal approach was pursued to maximize the choice of robust models available for any given season. In additon, adequate sample sizes were available for a seasonal approach to be completed and in this way each season is treated independently. However, for comparative purposes the sighting data were pooled over the four seasons and evaluated using the same model fitting procedures.

Variance estimates for each computed density value were computed based on the results of the distributional analysis as in Thompson and Shoop (1981). Approximate 95% confidence intervals are presented as $\pm$ 2 standard errors about the mean value for D.

Density estimates were expanded to estimates of numerical abundance as:

$\hat{N} = \hat{D} \cdot A$

$\hat{N}$ = numerical estimate

$\hat{D}$ = density estimate

A = total area surveyed.

Values of $\hat{N}$ are accompanied by variance estimates computed after Burnham, Anderson, and Laake (1980).

Three studies, thus far, have investigated the amount of time C. caretta spend at the surface on a daily basis. Two studies utilized remote sensing to evaluate surface time for animals in the wild (Kemmerer, Timko and Burkett, 1982; Musick, Byles, and Billamund, 1983). One study examined surfacing behavior as a function of respiration in the laboratory (Lutcavage and Lutz, 1983). In the two field studies, the mean percent of time C. caretta spent at the surface in a 24-hour period was (with 95% confidence limits) 3.8% (± 0.27%) for C. caretta in Cape Canaveral, Florida in September and October, 1981 (Kemmerer et al., 1982); and 5.2% (± 1.2%)(Musick et al., 1983). In the laboratory experiment surfacing time was highly variable and dives ranged from 1 minute per hour to 44 minutes per hour. The Kemmerer et al. (1982) results are used herein because this study occurred in Cape Canaveral, Florida, which is within the NMFS/SEFC aerial survey study area, and is within the area of demonstrated concentration of C. caretta. However, it is notable that the two field studies yielded similar results.

Kemmerer et al. (1982) demonstrated that in the fall of 1981 C. caretta were at the water surface an average of 3.8% of each 24 hour period of observation. In each hour, turtles averaged 2.2 minutes (± 1.8 min) at the surface. Thus, .038 (p) is the proportion of the total population along the track line that is sampled at any given time, where

$pN = n/N$

p = estimate of the proportion of the population that is sampled

n = sample size

N = population size

and for N:

$N = n/p$

Given this binomial probability, p, the variance of p is:

$Var(p) = p(1-p)/N$

This means that if p represents the proportion of turtles present (*C. caretta*) actually observed, then (1-p) represents the proportion of turtles that were presumably present but not at the surface. Thus, for each block and survey, sample sizes can be corrected to actual population values for each transect and block. The new sample sizes are used to directly estimate N' as:

$N' = n'/s$

N' = numerical abundance of animals at and below the surface

n' = corrected sample size or population

s = level of sampling effort in that block and survey, given animals are randomly and uniformly distributed

Values of N' estimated with this correction for surface time presumably represent all age or size classes of *C. caretta* within that sampling block for that season. However, utilizing the correction factor to estimate animals at the surface and below the surface assumes that aerial observers cannot identify *C. caretta* when they are below the surface. This is *not* the case. According to T. J. Thompson (pers. comm.) observers were able to positively identify C. caretta that were 5 feet below the surface. These animals would be indicated by Kemmerer et al., as below the surface. In addition, according to T. J. Thompson (pers. comm.), it is likely some animals were observed and identified to species level 12 feet below the surface of the water. Therefore, it appears that the values of N' are biased and are probably inflated. However, the magnitude of this bias is not known. To properly correct for estimates of abundance for the proportion of time animals are at the surface would require continued radiotelemetry work which would allow for the determination of depth at location. In addition, the Kemmerer et al. (1982) study was necessarily limited temporally and spatially. Continued work would necessarily have to be completed with larger sample sizes in different locations and at least seasonally with animals of varying sizes to define surface times and provide an unbiased estimate of surface time.

Results and Discussion

Distributions and Sightability

Of the total 2,690 turtles positively identified, 1,191 (81.8%) were identified as C. caretta, 98 (3.7%) as D. coriacea and 359 (14.5%) as unidentified, or of unknown species but probably not D. coriacea.

Distribution maps for sightings of C. caretta and D. coriacea for the four surveys are presented in Figure 3. These species were the most frequently reported during the four surveys. The actual observations of turtles, by species (for C. caretta and D. coriacea) sighted by block for each survey are presented in Figures 4 and 5. These figures can be compared to the transects "made-good" for each survey (Figure 6). It is apparent that the simple random sampling design was successfully implemented (Figures 3-6). Given this design, perusal of Figures 3-6 suggest that turtles apparently are not randomly distributed throughout the study area during the spring and summer. When blocks are treated as equal area quadrats, and the Index of Dispersion ($I = v/m$) is calculated for each survey, this non-random spatial distribution is demonstrated significantly ($p < .05$) for C. caretta which has ample sample sizes for the application of this method (Table 2). The X^2 values approximate each computed value of I with n-1 degrees of freedom, and it is concluded that C. caretta are not randomly distributed throughout the study area in the spring and summer. The values of I (X^2) for these two seasons differ significantly from 1, and in a positive direction suggesting that animals are clumped and the underlying statistical distribution reflected by clumping is usually a negative binomial (Seber, 1982). The actual clumping of C. caretta appears to be most concentrated within area 8 and the northern third of area 9. The fall and winter surveys do not demonstrate any statistically significant deviation from randomness of C. caretta within the study area. The winter survey very closely resembles a random or Poisson distribution with an approximate Chi-square value of 3.84 with a level of significance (p) less than .900. Thus, there is a significant contagious distribution of C. caretta in the spring and summer and apparent random distribution in the fall and winter within the study area from North Carolina to Key West, out to the western boundary of the Gulf Stream. During the summer survey two Gulf Stream areas were sampled. These areas were not of area equal to the 10 blocks and were not included in this quadrat analysis. However, examination of Figures 4 and 6 demonstrates that while turtles were observed in these areas but largely in the Gulf Stream western boundary waters. Thus, clumping is a result of the prevalence of turtles along the Gulf Stream boundary with few sightings in the Gulf Stream proper. This is consistant with the results of Hoffman and Fritts (1982).

Results of computing values of I for individual transects, with sample sizes $\geq$ 5 demonstate randomness of C. caretta along transects "made good". In the spring, only 6 of 45 (13%) transects analyzed demonstrated values of I that were significantly different at $p < .05$ from 1. During the summer, fall and winter surveys 4 of 36 (11%); 3 of 14 (21%); and 2 of 8 (25%) transects demonstrated random distributions of C. caretta. The sample sizes in the spring and summer are sufficient for this approach. However, the sample sizes (4 and 8 transects respectively) in the fall and winter may not be adequate for this approach.

The occurrence of transects within a block demonstrating C. caretta randomly distributed with transects in the same block demonstrating clumping may be due to the transects intercepting animals within irregularly shaped clumps, as suggested by T. J. Thompson (pers. comm., 1983). If turtles are clumped but form irregularly shaped clumps, then it would be expected that some transects, given random placement, will intercept a small area where C. caretta are present. These transects will demonstrate clumping. Other transects passing through an extensive area of turtle distribution may be described as a random distribution.

The three potential environmental correlates measured which may effect turtle distributions were depth, sea surface temperatures (used as an index for water temperature) and the presence of other animals. Not measured are the potential other factors such as the pattern of resources or breeding activity. A canonical correlation was completed to attempt to describe the possible causes for clumping. Cannonical correlations were performed for each season, using these data pooled over the four seasons; and with data pooled over the spring an. summer surveys, and the fall and winter surveys. The resulting correlation matrices are presented in Tables 3 and 4. This technique is used only for descriptive purposes, and examination of Tables 3 and 4 reveals interesting trends. Seasonal comparisons can be made from examining Table 4. Significant positive correlations are identified between the occurrence of C. caretta and sea surface temperature in the spring, summer, and winter (no linear relationship in fall); between the occurrence of unidentified turtles and depth in the fall; and D. coriacea and other species in the spring. Significant negative correlations are identified between D. coriacea and water temperature in the spring, fall and winter; between C. caretta and other species in all four seasons; and between unidentified turtles and other species in the spring, fall and winter. Even in the winter, it appears that D. coriacea is not dependent upon warm temperatures and is likely associated with cooler, perhaps more productive waters than C. caretta. The occurrence of C. caretta is positively associated with water temperature in the spring and summer. This may be a result of the breeding season which is focused off the east coast of Florida and where the warmest waters are encountered during these two seasons. In the winter the positive relationship is likely a result of C. caretta preferring to remain in the warmer boundary waters as suggested by the actual spatial distribution observed for this season (Figure 4).

The positive relationship described between _D. coriacea_ and other species again may reflect a lack of dependence on water temperature and a preference for more productive areas where other animal species would be expected to occur. The negative relationship between _C. caretta_ and other species may be a real phenomenon. However, it may be an observer response to focusing on _C. caretta_ in high density areas while sacrificing the reporting and recording of other species. The results for unidentified turtles (which are probably mostly _C. caretta_ based on relative frequency of occurrence) are consistent with those of _C. caretta_. The only significant relationship (positive) between turtles and depth is demonstrated by unidentified turtles in the fall. This relationship is consistent with positive correlation between unidentified turtle and water temperature. Again, there may be a preference for the warm Gulf Stream boundary waters, which are also in the greatest depths in the study area. The lack of significant correlation between _C. caretta_ and _D. coriarea_ with depth is likely due to the actual benthic topography of the sampling area which is relatively flat from the coast out to the Gulf Stream (0-200 fathoms), with the majority (80.5%) of the study area of less than 80 fathoms. It appears that water temperature is the most significant factor of those measured effecting _C. caretta_ distributions within our study area. In Table 4 the results of the canonical correlation analysis on the pooled data are presented. While these results are numerically supportive, they offer no additional enlightenment regarding the possible effects of depth, temperature, and the presence of other species on the distributions of turtles.

When the study area is approportioned by depth strata and these proportions compared to the proportion of total frequency of _C. caretta_ and _D._

coriacea by depth strata, there is a strong positive correlation between these proportions. This suggests that turtles do not demonstrate any depth preference within our study area. However, C. caretta are observed in the warmest water which prevailed during these surveys, and D. coriacea appear to prefer water about 20°C ($\pm$ 5°) (Table 5).

Two additional survey blocks were sampled in the summer in the Gulf Stream proper. Of the 37 C. caretta sighted within these areas (36 in the southern Gulf Stream area and 1 in the northern Gulf Stream area) all but 2 (1 in each area) were sighted along the inner portion of the western boundary of the Gulf Stream. This suggests that in the summer, the actual western boundary for C. caretta is the Gulf Stream proper. Only 1 D. coriacea and 2 unidentified turtles were sighted in the Gulf Stream sampling areas. These results are similar to those reported by Hoffman and Fritts (1982) in their August, 1980 aerial survey of the same area off Cape Canaveral.

A table of C. caretta sightings classified by season (4 levels), survey block (10 levels), Beaufort sea state (5 levels), turbidity (5 levels), and glare (3 levels) was analyzed to measure the potential effects of each on the actual frequency of turtles sighted. All possible combinations of these factors (2, 3, and 4 way) were also analyzed. Results of the analysis of this multidimensional contingency table is presented in Table 6.

The results from this analysis demonstrate that significantly different numbers of C. caretta were reported between seasons, between blocks, for different values of Beaufort sea state, glare and turbidity. Each possible interaction also yielded significant ($p \leq .05$) results. The effects of these factors on the frequencies of each survey were examined using the same analysis. Results of these analysess are presented in Table 7, and it is concluded that the frequency of sightings of C. caretta were different between seasons, between sampling blocks, and for different amounts of glare, sea state, and water clarity.

The significant difference demonstrated in turtle frequencies between seasons and blocks was expected given the previous results of the distributional analysis. The resulting frequency distributions are presented in Figure 7. Spearman rank correlation coefficients were computed comparing the proportions of frequencies of C. caretta and D. coriacea sighted by glare amount, sea state and water clarity with the proportion of the total miles flown reported for each value of these three parameters. Results are presented in Table 7 and the frequency distributions are presented in Figures 8 to 10. The proportions of both species are positively correlated with the proportion of miles reported for each value of glare and clarity. Thus, while the frequency of sightings classified by glare and clarity differed significantly for values of each, these frequencies are positively correlated significantly to the proportional occurrence for the values for each, i.e., frequencies are correlated with effort. However, no significant ($p > .05$) correlation was demonstrated for sea state. While sea state 3 predominated, both C. caretta and D. coriacea were seen more frequently in sea state 1 suggesting that increasing sea state has a negative impact on turtle sightability. This impact is directed at effectively reducing the observation swath width. The frequency of sightings of C. caretta were cross-classified by sea state and sighting interval (in 1/16 nm increments) and cell frequencies were compared with a χ^2 contingency test. This table and the χ^2

results are presented in Table 8. These results indicate that as sea state increases the absolute frequency and proportion of sightings decrease in sighting intervals 3 and 4. Ultimately, the effect of sea state could potentially impact the sightability or detection curve, the pdf selected, the value of f(0) and resulting density estimates (D). A second negative bias would be introduced if sea states reduce the sample sizes (n). The potential impact of sea states will be quantified using results from a special experimental survey completed in July/August 1983, specifically addressing the effect of sea states in turtle sightability.

The predominance of sea states 3-4 during the fall survey (61.8% of total transect miles flown) may have effectively resulted in decreasing the sightability of turtles. The greatest frequency of sightings of _C. caretta_ occurred in area 1 during the fall, which was the only area that consistently had sea states of less than 3. Thompson and Shoop (1983) postulate that the peak in sightings in the fall in area 1 may be a result of the higher sea states in areas 2-10. However, an alternative hypothesis that cannot be discounted and presented by Thompson and Shoop (1983) suggests the concentration of turtles in area 1 is not related to sea states but may reflect an influx of turtles moving from northern and eastern waters. The northern distribution of _C. caretta_ and _D. coriacea_ off the eastern U.S. was defined by CeTAP surveys (CeTAP Final Reports 1982; 1981; 1980). During these surveys the greatest frequencies of _C. caretta_ and _D. coriacea_ sightings occurred off North Carolina, north of Cape Hatteras. Thompson and Shoop (1983) suggest that these turtles migrate south into NMFS area 1 where a predictable increase in turtles would be observed in the fall.

Thompson and Shoop (1981) demonstrated a diurnal effect on the frequency of sightings of C. caretta. A statistically significant peak in the sightings of C. caretta was observed (using 1979 CETAP data) $\pm$ 3 hours around noon. A X^2 goodness of fit test was completed comparing the C. caretta sightings classified by hourly interval and by season. The X^2 results are significant at $p \leq .0001$. The total sightings were pooled over the four seasons and the resulting frequency distribution is presented in Figure 11. This figure includes the frequency distribution for D. coriacea sightings but sample sizes were not adequate for further analysis for this species. The null hypothesis of equality of cell frequencies (i.e., hourly interval) is rejected for the spring, summer and winter surveys. For each season peaks respectively at 1300, 1100, and 1100 hours are demonstrated (Table 9). The cell frequencies are statistically equal in the fall and the distribution is uniform over hourly intervals. It is impossible to determine what causes these peaks in frequency of sighting at these hours. As suggested by Thompson and Shoop (1981) it may be a result of turtle behavior and distributions or a function of observer behavior. However, the significant results are consistent with those of Thompson and Shoop (1981).

Density Estimates

Caretta caretta

Two approaches were followed in estimating C. caretta density. First, each season was treated as an in independent sample. For each season, a detection curve was fitted to the several models available, and a value for $\hat{f}(0)$ was selected utilizing the criteria of Burnham et al (1980). The seasonal detection curves used in model fitting are presented in Figure 12.

Note that data were pooled over intervals 4 and 5 or 3, 4 and 5. This pooling reduces the bias around the value of $\hat{f}(0)$. In each detection curve a shoulder is evident around $x = 0$, such that the rate of change of frequency relative to distance from the transect is zero. This indicates that the sighting intervals used were correct for estimating C. caretta density. Independent density estimates ($\hat{D}_i$) were first derived for each sampling block (i). An average density ($\hat{D}$) for the study area (i.e., overall blocks) for each survey was also derived. Values for $\hat{f}(0)$ by season with: total line length in nautical miles (L); sample sizes and variance (n); model selected; the standard error of $\hat{f}(0)$(as X^2 var $\hat{f}(0)$); computed effective half swath width (as $1/\hat{f}(0)$; and X^2 goodness of fit value of model with level of significance (p) are presented in Table 9. Density estimates by block and for the survey with: var ($\hat{D}$); numerical abundance ($\hat{N}$) and var ($\hat{N}$) are preented in Table 10. In the spring and fall, the Fourier series was selected (one and two term respectively, FS1 and FS2). While this model is not a true pdf, it is considered robust and meets all the criteria for robustness of Burnham et al (1980). For the summer and winter the exponential power series (np power) was selected. This parametric model is considered robust and also meets the selection criteria of Burnham et al (1980). In particular this model is shape flexible and the generalized model is:

$$g(x) = \exp - (x/a)^b$$

where

a = scale parameter ($0 < a$)

b = shape parameter ($0 > b$)

For $b = 1$, the model becomes a negative exponential which is not robust and can produce biased results. In the two surveys where the exponential power series was selected values for b were: 4.82 (summer) and 2.85 (winter). As b increases, the curve tends to flatten around $x = 0$. This shape flexibility, with a shoulder around $x = 0$, in addition to the minimal bias around $f(0)$, prompted selection of this parametric model for the summer and winter.

The second approach utilized all the sighting data pooled over the four surveys to estimate $f(0)$. The resulting frequency distribution is presented in Figure 12. The exponential power series was selected ($b = 3.92$) and results are presented in Table 10.

Graphical comparisons between $f(0)$ values were completed with $\pm$ 2 SE $f(0)$ as approximate 95% confidence intervals (Figure 13). The $f(0)$ values for the fall vs winter and spring vs summer are not significantly different (approximate $p > .05$). However, the fall and winter differ significanly from the $f(0)$ values for the spring and summer. This indicates that each season be treated as independent and these results are considered more appropriate in density estimation.

Density estimates by block and by survey are presented in Table 10. The variance for density (var (D)) was computed as:

$$\mathrm{Var}\ (\hat{D}) = (\hat{D})^2[(cv(n))^2 + cv(\hat{f}(0))^2]$$

where

$$cv(n)^2 = var(n)/n^2$$

$$cv(\hat{f}(0))^2 = \frac{var(\hat{f}(0))}{(\hat{f}(0))^2}$$

This table includes values of N and var(N). The var(N) was computed indirectly as:

$$var(\hat{N}) = A^2[cv(\hat{D}))^2]$$

and winter are not significantly different ($\pm$ 2 SE as approximate 95 confidence intervals). However, stratification of the fall/winter survey effort is being implemented in November, 1983.

The reciprocal of the estimated $\hat{f}(0)$ values gives the value of the effective half swath width (w) for C. caretta. For each survey the effective swath width (2w) was computed as: .222 nm; .270 nm; 0.176; and 0.185 nm for the spring, summer, fall and winter surveys respectively. Again, sea states were highest in the fall which probably reduced the swath width in this season. The estimated effective swath width resulting from the pooling of these surveys was 0.234 nm. The realized sampling coverage for the study area given the above four values for swath width are approximately 5.2%, 6.3%, 4.1%, and 4.3% respectively.

It was shown that the frequency of Caretta caretta sightings differ significantly by hourly intervals. In addition the effect of increasingly Beaufort sea state is to reduce the absolute frequency of sightings and decrease the effective swath width sightings occur within. These results were used to design an experimental survey completed in June, 1983 with results pending. The primary purpose of this experiment was to definitively quantify the effects of these two parameters on estimation procedures and derive a correction factor with which to adjust estimated turtle densities. To properly derive such a correction factor, an area of known density was selected and surveyed under varying sea state conditions (0-5), during different hourly intervals. In this way, while controlling alternatively sea state and "time of day", the other condition ("time of day" and sea state respectively) can be evaluated quantitatively. Because the first year surveys were specifically designed to discern distributions and produce preliminary estimates of density and abundance and not to precisely quantify the effects of sea state and time of day, resulting estimates are not adjusted to reflect the potential impact of these factors on density. The progress report following the completion of the second year surveys, will specifically address these factors as a result of the special experimental survey designed to answer these questions.

Utilizing the results of Kemmerer et al (1982), values of $\hat{N}$ were computed using p = .038 to correct sample sizes. These results are presented in Table 11. These values are likely biased because of the ability of observers to sight and identify turtles up to 12 feet below the surface in some areas as previously discussed. The direction of this bias is positive but the magnitude is unknown. However, the results of Kemmerer et al (1982) are consistent with those of Musick and Byles (1983) and Lutcavage and Lutz (1983). In all three studies the amount of time turtles were at the surface (breathing) was extremely short. The ratio of sub-surface to surface time in Kemmerer et al., (1982) averaged about 15:1, in Musick and Byles (1983) 21:1 and in Lutcavage and Lutz (1983) about 15:1 to 20:1. It appears that utilizing sample sizes and by completing these experiments in other areas at different times of the year and with varying the sizes of individuals may result in refined estimates of abundance. However, without this correction factor, the minimal density estimates are extremely precise suggesting that these aerial surveys for C. caretta produced the desired answers.

An independent estimate for C. caretta females nesting along the coast of this study area was the result of quantifying data collected under the same survey effort utilizing a different platform, experimental design and personnel. Thompson (1983) estimates the number of C. caretta nesting in 1982 as 28,884 (SE = 6,572). Given this value as Powers (J. E. Powers, pers. comm.) postulates if turtles nest every two years and using a 1:1 sex ratio, then the adult loggerhead turtle population is estimated as 2x2x28,884 = 115,536. It can be assumed then, that the values in Table 11 (for abundance correcting for surface times) represent all turtles of all size categories, including the 115,536 adults. Thus, the order of magnitude of corrected abundance estimates appear reasonable, given the above hypothesis on nesting females.

The poor precision associated with these corrected values for abundance reflects the lack of definition between surface and sub-surface behavior. The uncorrected values however are very precise and represent the first empirically derived estimates of abundance of C. caretta in the pelagic environment in the southeast U.S. Other estimates are available for turtles off the northeast U.S. However, because these surveys were multi-species with marine mammals as the primary target, turtle abundance estimates are of lower precision than those presented in this report. In the CeTAP surveys the coefficient of variation for C. caretta abundance estimates range from about 12% to at least 140% (G. P. Scott, Jr. pers. comm). In the NMFS southeast turtle surveys, using a simple random sampling design in the first year, the precision for the seasonal surveys was approximately equal to or less than 10% except for the winter survey. This precision is likely to improve with stratification of sampling in the second and third year surveys.

Thus, these results from the first year represent the best available estimates for *C. caretta* in the southeast U.S., and these estimates will improve as a result of the second and third year surveys.

Conclusion

The precision associated with the abundance estimates (uncorrected for surface time) support the use of aerial surveys to provide data used in abundance estimation. The results of this first year of surveys presented herein were used to design the second and third year sampling programs. In the second year of sampling the sampling scheme included stratification of effort spatially in the summer and fall surveys to optimize coverage in areas 7-10. The second year includes an experimental survey completed in June 1983 to provide data which will be used to examine the effects of sea state and the diurnal behavior of turtles in turtle sightability and therefore density estimates. In the third year, in addition to completing seasonal surveys, it is anticipated that a survey designed to evaluate sizes of turtles will be completed. These data can be used in determining the size structure of the observable pelagic population. Annual abundance values will be compared to initiate trial analysis, and will be used in population projection models to assess the status of stock of turtles in the southeast.

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Table 1. Number of transects flown and "made-good" for each survey and block. NF = not flown.

Survey No.	Block Number 1	2	3	4	5	6	7	8	9	10	11	12
1	26	14	13	13	12	13	10	11	15	28	NF	NF
2	26	14	13	13	11	10	9	10	17	30	6	8
3	22	14	13	15	11	9	9	14	19	30	NF	NF
4	NF	10	14	12	10	8	9	10	18	26	NF	NF
Total	74	52	53	53	44	40	37	45	69	114	6	8

Table 2. Results of quadrat analysis for four seasonal surveys. The computed approximate x^2 value tests the hypothesis of randomness of *C. caretta* throughout the study area. Included are the computed mean number of *C. caretta* for each season ($\bar{x}$) and variance (S^2) and the x^2 value with level of significance, p. The value of x^2 is derived as as the Index of Dispersion or $S^2/\bar{x}$. Both spring and summer demonstrate non-random spatial patterns ($p < .05$) and the null hypothesis is rejected. The null hypothesis is accepted for the fall and winter.

Season	$\bar{x}$	S^2	x^2	p
Spring	79.90	13000.09	162.70	$<.005$
Summer	91.90	22158.29	241.11	$<.005$
Fall	22.70	305.61	13.49	$<.250$
Winter	28.00	107.50	3.84	$<.900$

Table 3. Computed correlation coefficients by season between dependent variables *Caretta caretta* (CC), *Dermochelys corriacea* (DC) and unidentified turtles (UK) and independent variables depth (DEPTH), sea surface temperature (TEMP) and presence of animals (SPECIES). Included are significance levels (p).

	TEMP	P	DEPTH	P	SPECIES	P
SPRING						
UK	-0.0089	>.05	-0.0214	>.05	-0.0802	<.05
CC	0.1002	<.05	0.0553	>.05	-0.7008	<.01
DC	-0.1274	<.01	0.0028	>.05	0.0763	<.05
SUMMER						
UK	-0.1041	<.05	-0.0168	>.05	-0.0583	>.05
CC	0.0831	<.05	0.0296	>.05	-0.6314	<.01
DC	-0.0262	>.05	-0.0167	>.05	-0.0208	>.05
FALL						
UK	0.1172	<.05	-0.1046	<.05	-0.1933	<.01
CC	-0.0133	>.05	0.8149	>.05	-0.6424	<.01
DC	-0.3507	<.01	-0.0218	>.05	-0.0910	>.05
WINTER						
UK	-0.0626	>.05	-0.0334	>.05	-0.1642	<.01
CC	0.1251	<.05	-0.0057	>.05	-0.6192	<.01
DC	-0.399	<.01	-0.0278	>.05	-0.0923	>.05

Table 4. Correlation coefficients for spring and summer; fall and winter; and all four seasons pooled. Correlation coefficients are used to describe linear relationships between the dependent variables (frequencies) (DC); between *C. caretta* (CC), *D. coriecea* (DC) and unidentified turtles (UK); and the independent variables depth (DEPTH), sea surface temperatures (TEMP) and the presence of other species (SPECIES). Included are approximate levels of statistical significance (p).

	TEMP	p	DEPTH	p	SPECIES	p
Spring and Summer						
UK	-0.0382	>.05	-0.0187	>.05	-0.0633	<.05
CC	-0.0391	>.05	0.0453	>.05	-0.6372	<.01
DC	-0.0507	>.05	-0.0062	>.05	0.0387	>.05
Fall and Winter						
UK	-0.0329	>.05	0.0484	>.05	-0.1784	<.01
CC	-0.0370	>.05	0.0468	>.05	-0.6303	<.01
DC	-0.0350	>.05	-0.0239	>.05	-0.0923	<.01
Four Seasons						
UK	-0.0862	<.01	0.0096	>.05	-0.0887	<.01
CC	0.3236	<.01	0.0370	>.05	-0.6714	<.01
DC	-0.0023	>.05	-0.01103	>.05	-0.0398	>.05

Table 5. Proportion of total effort (EFFORT) in lineal nautical miles "made good" for values of depth; sea surface temperatures; amount of glare; water clarity and Beaufort sea state. Proportions of sighting of both *C. caretta* (CC) and *D. coriacea* (DD) are included. Spearman rank correlations (r) coefficients are presented, and those that are significant at $p < .05$ are indicated with an asterisk(*).

DEPTH (in fathoms)

	10	30	50	60	80	100	125	175	350	750	1500	3000	4000	r
EFFORT	.214	.167	.177	.083	.164	.031	.022	.030	.054	.020	.010	.031	.004	
CC	.170	.190	.280	.100	.190	.020	.020	.020	.010	.010	.003	.010	.030	0.830*
DD	.080	.360	.270	.080	.160	.030	.010	.000	.000	.000	.000	.010	.000	0.870*

TEMPERATURE (°C)

	0	5	10	15	20	25	30	r
EFFORT	.000	.150	.000	.064	.187	.282	.293.	
CC	.000	.000	.000	.010	.140	.370	.490	0.940*
DD	.000	.000	.000	.010	.390	.250	.340	0.770

GLARE

	1	2	3	4	r
EFFORT	.440	.340	.170	.050	
CC	.180	.410	.090	.020	1.00*
DD	.560	.310	.120	.010	1.00*

Table 5 (Continued)

	WATER CLARITY			
	1	2	3	r
EFFORT	.820	.120	.060	
CC	.880	.110	.010	1.00*
DD	.880	.060	.050	1.00*

	SEA STATE					
	0	1	2	3	4	r
EFFORT	.050	.240	.250	.340	.100	
CC	.100	.100	.260	.200	.040	.050
DD	.030	.110	.530	.130	.070	.050

Table 6. Results of multidimensional contingency analysis of the frequency of *C. caretta* sightings classified by season (N), block (B), sea state (S), glare (G), and turbidity (T). Presented are the independent effects of these variables on the sightings of *C. caretta*, and the two, three and four way interactions, with the computed Pearson Chi-square for that log-linear model level of significance (p) and degrees of freedom (DF). All possible combinations are examined and all levels are significant indicating all parameters effected the numbers of turtles sighted.

Model	Pearson χ^2	P	DF
One way	28830.34	<.0001	6692
Two way	12319.58	<.0001	3911
Three way	1548.38	<.0001	707
Four way	61.04	.0001	26

Table 7. Results of x^2 multi-contingency table analysis for surveys 1-4. Included are the results of examining the one-way effects of block, sea state, glare and turbidity; the two-way interactions of block-sea state, block-glare, block-turbidity, sea state-glare, sea state-turbidity, and glare-turbidity; and the three way interactions of block-sea state-glare, block-sea state-turbidity and sea state-glare-turbidity. Each model in accompanied by degree of freedom (DF), Pearson Chi-square value (x^2) and level of significance (p). All p values are highly significant indicating all parameters effect the numbers of turtles observed.

Model	DF	x^2	p
		<u>Survey 1</u>	
one way	1655	5945.93	<0.0001
two way	636	1266.35	<0.0001
three way	114	284.34	<0.0001
		<u>Survey 2</u>	
one way	1446	6060.48	<0.0001
two way	430	604.79	<0.0001
three way	77	76.76	<0.0001
		<u>Survey 3</u>	
one way	1237	5662.72	<0.0001
two way	375	1128.18	<0.0001
three way	37	200.66	<0.0001
		<u>Survey 4</u>	
one way	924	8073.13	<0.0001
two way	179	644.61	<0.0001
three way	30	127.02	<0.0001

Table 8. Frequency of *C. caretta* sightings classified by sea state and sighting interval. A x^2 contingency test comparing all frequencies resulted in $x^2 = 68.70$ for 16 degrees of freedom. This x^2 value is significant at $p \leq .005$.

Sighting Interval	Sea State 1	Sea State 2	Sea State 3	Sea State 4
1	287	245	191	4
2	273	180	118	21
3	77	27	12	0
4	2	0	0	1
5	0	0	0	0

Table 9. Frequency of *C. caretta* sightings classified by season and hour of occurrence (hourly interval). Within season comparisons between frequencies were completed and resulting x^2 values and levels of significance (p) are presented. Those values of p that are $<.05$ are considered significant, and the null hypothesis of equal cell frequency is rejected.

	Time in Hourly Interval							
SEASON	0900	1000	1100	1200	1300	1400	x^2	p
Spring	46	60	91	130	152	117	98.70	$<.005$
Summer	72	82	188	157	126	54	113.80	$<.005$
Fall	18	82	20	24	26	33	7.35	$<.250$
Winter	12	21	41	29	31	23	18.68	$<.005$

Table 10. Values by season and pooled over four seasons for: total transect length (L) flown; sample sizes (n); model selected as pdf 1 term Fourier Series (FS1), 2 term Fourier Series (FS2) and exponential power series (exp power); intercept of pdf, f(0); the standard error for f(0) computed as 2 var(f(0)); w where w is 1/f(0); x^2 goodness of fit of model; and level of significance (p) of the x^2 values. NC indicates not computed because of no degrees of freedom, resulting from data pooled over sighting intervals.

	Spring	Summer	Fall	Winter	Spring-Winter
L	6634	7008	6438	5070	25150
n	654	681	174	160	1669
Var(n)	654	681	174	320	1669
model	FS 1	exp power	FS 2	exp power	exp power
f(0)	9.040	7.425	11.40	10.840	8.573
SE f(0)	.088	0.253	0.846	1.050	0.216
w	.111	0.135	0.088	0.0923	0.117
x^2	.435	0.0120	NC	13.97	2.014
p	0.509	0.994	--	0.0002	0.365

Table 11. Survey results by block for each survey season, and pooled over blocks for each season (All Blocks). The values for each block are in order: sample size (n); density in numbers per square nautical miles; var (D); N; and the standard error y (N) computed as $\sqrt{\text{var (N)}}$.

SURVEY	BLOCK 1	2	3	4	5	6	7	8	9	10	11	12	All Blocks
Spring	70 0.480 0.00004 1517 42	18 0.132 0.00003 404 128	116 0.727 0.0009 2141 122	15 0.103 0.00002 314 132	36 0.203 0.00007 589 119	29 0.180 0.00005 586 128	83 0.671 0.0007 2221 131	413 2.700 0.0118 7846 117	80 0.678 0.008 2076 128	49 0.337 0.0002 1020 127			909 0.619 0.0006 18996 1187
Summer	22 0.130 0.00004 411 154	7 0.470 0.0012 1438 226	6 0.042 0.00005 124 157	15 0.078 0.000016 238 175	15 0.085 0.000019 247 48	32 0.182 0.00009 593 54	42 0.226 0.00013 748 167	470 2.700 0.0192 7846 149	284 1.800 0.0085 5512 157	26 0.159 0.00007 481 159	2 0.023 0.000001	45 0.405 0.0004	919 0.487 0.0006 14932 477
Fall	80 0.625 0.0070 198 264	34 0.321 0.0012 982 330	19 0.512 0.0003 448 336	21 0.165 0.0003 502 320	2 0.022 0.000005 64 295	8 0.073 0.00006 238 350	13 0.120 0.0002 397 390	20 0.175 0.0004 509 332	23 0.202 0.0005 619 335	18 0.143 0.0002 433 299			227 0.201 0.0005 6164 671
Winter	NB	NB	14 0.134 0.0002 394 334	27 0.246 0.0008 749 352	22 0.181 0.0004 525 325	30 0.315 0.0013 1026 349	43 0.335 0.0014 1109 324	5 0.056 0.0004 163 116	6 0.054 0.00004 165 388	2 0.020 0.000005 605 338			149 0.159 0.0003 4877 3268
Spring thru Winter	161 0.360 0.0004 1138 176	30 0.143 0.0002 438 303	15 0.195 0.0002 574 214	78 0.124 0.0002 378 347	75 0.123 0.0002 357 334	99 0.168 0.0002 547 274	181 0.303 0.0004 1103 219	908 1.194 0.0015 3470 94	393 0.707 0.0009 2165 128	95 0.161 0.0002 487 266			2204 0.376 0.0005 11533 564

Table 12. Results of incorporating the correction factor for surface vs sub-surface times on sample sizes presented in Table 11. Included in order are corrected sample sizes (n'); N, and the standard error of N.

SURVEY	BLOCK 1	2	3	4	5	6	7	8	9	10	11	12
Spring	1,042	474	3,052	395	947	763	2,104	10,868	2,105	1,290	NF	NF
	30,750	8,770	58,692	6,077	16,302	14,367	42,000	209,000	40,480	24,807		
	40,230	33,907	120,736	4,495	18,711	14,936	73,083	827,967	69,153	33,167		
Summer	579	104	158	395	395	842	1,105	12,368	7,474	604	53	1,184
	9,191	2,921	2,508	6,270	6,270	13,365	17,540	196,317	118,635	10,857	841	18,794
	8,234	1,476	1,173	4,638	4,638	14,440	21,711	812,895	381,856	10,573	227	24,079
Fall	1,016	895	500	553	53	211	342	526	604	474		
	44,293	21,829	12,195	13,408	1,293	5,146	8,341	12,829	14,756	11,561		
	22,220	24,311	10,153	11,806	3,493	2,700	5,744	10,958	13,516	9,368		
Winter	NB	NB	368	711	579	789	1,132	132	158	53		
			8,762	16,535	13,165	18,349	26,376	3,069	3,674	1,233		
			6,262	16,411	11,794	19,196	31,872	1,311	1,719	333		
1-4	424	1,553	395	2,053	1,974	2,605	4,736	23,895	10,342	2,500		
	8,480	31,060	7,900	41,060	39,480	52,100	95,260	477,900	206,840	50,000		
	20,551	31,947	5,844	69,262	75,028	133,877	244,781	2,750,473	783,173	93,081		

Figure 1. NMFS/SEFC study area for pelagic surveys. Each area is approximately 3000 nm^2.

Figure 2. Field form utilized by observers during pelagic surveys to record sighting and environmental data.

Figure 3. Distribution of *Caretta caretta* and *Demochelys coriacea* sightings made during the four surveys from April 1982 to February 1983, excluding Gulf Stream areas.

Figure 4. Seasonal distribution of *C. caretta* sightings.

Figure 5. Seasonal distribution of *D. coriacea* sightings.

Figure 6. Transects "made-good" for each survey. Note in summer survay, the additional transects completed over the Gulf Stream.

Figure 7. Frequency distributions of sightings of *C. caretta* and *D. coriacea* by survey block and survey number or season. Blocks are numbered as in Figure 1 with the Gulf Stream northern area identified as 11 and the Gulf Stream southern area identified as area 12.

Figure 8. Frequency of sightings of *C. caretta* and *D. coriacea* classified by glare amount. Values of glare amount are 1 = none; 2 = slight; 3 = moderate and 4 = severe.

Figure 9. Frequency of sightings of *C. caretta* and *D. coriacea* classified by Beaufort sea state. Values of sea state range from 0 = flat to the maximum acceptable for surveying equal to 4.

Figure 10. Frequency of sightings of *C. caretta* and *D. coriacea* classified by clarity of water. Values for water clarity range from 0 = clear to 3 = turbid.

Figure 11. Frequency of sightings of *C. caretta* and *D. coriacea* classified by hourly interval.

Figure 12. Frequency distribution used in model fitting for *C. caretta* for each seasonal survey and pooled over the four seasons.

Figure 13. Graphical t-test comparing seasonal values computed for the f(0). Mean values of f(0) and ± 2 standard errors calculated as var(f(0)) are presented. Survey 1 is the spring survey, 2 = summer, 3 = fall and 4 = winter survey.

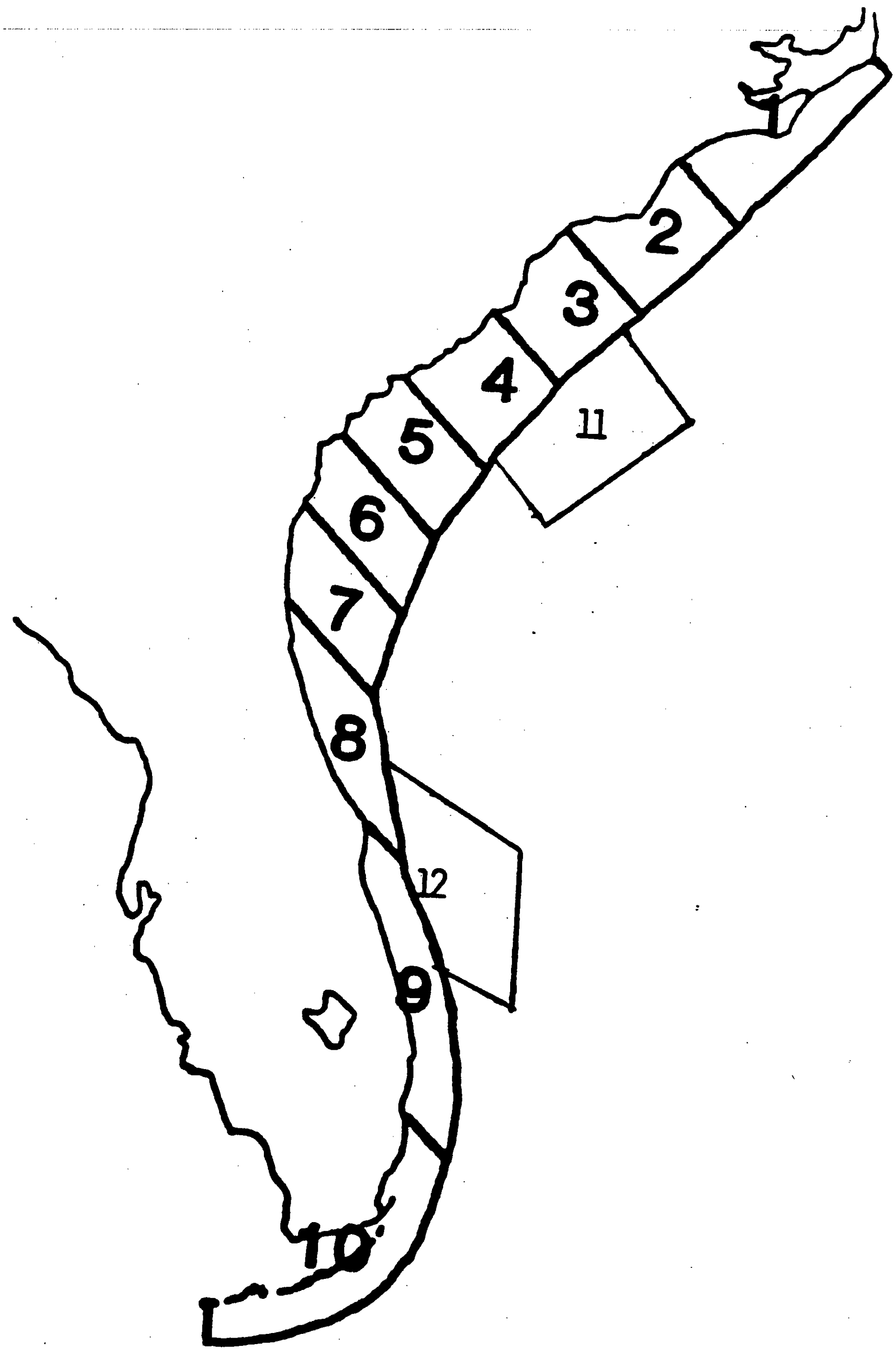
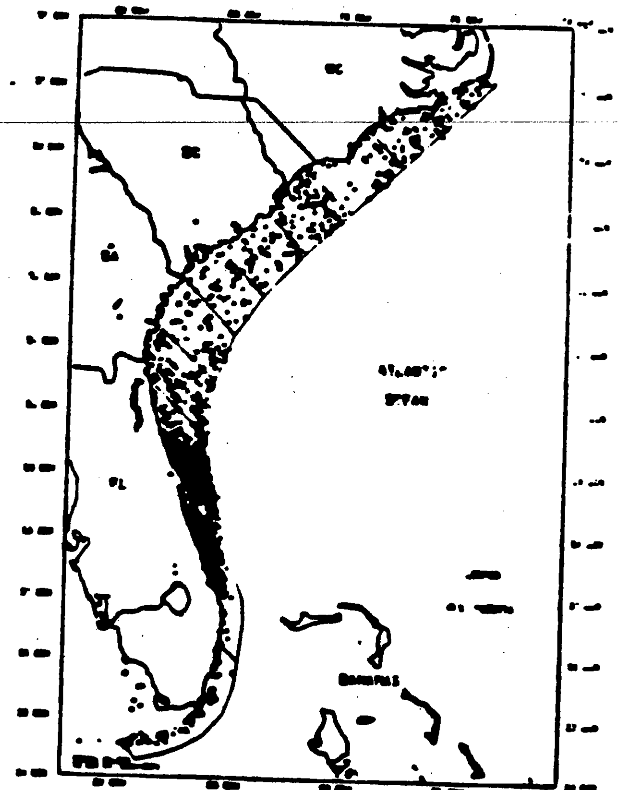


FIGURE 1. NMFS SEFC STUDY AREA FOR SEA TURTLE SURVEYS

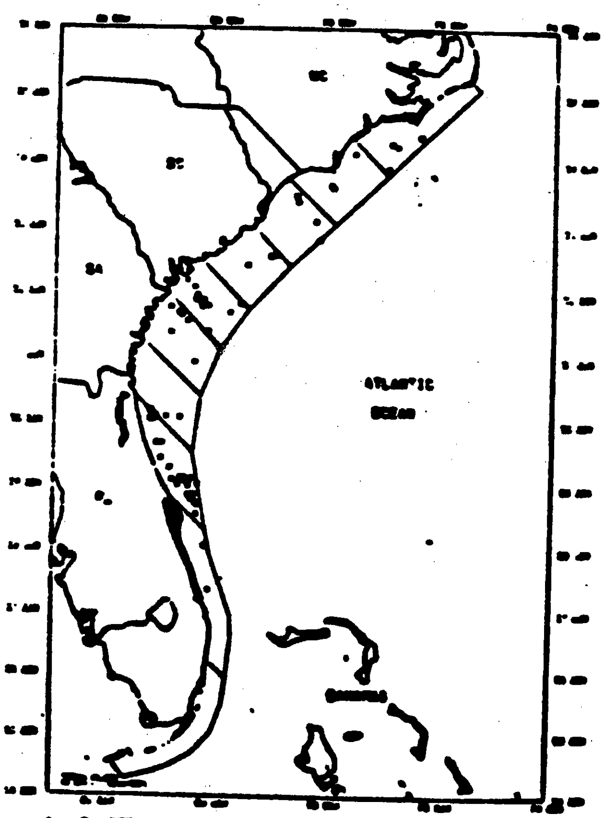
Observers: L______________ ( )/ R______________ ( )   Survey Area # ____   Date ____/____/____
Recorder: ______________ ( ) Pilot/Copilot ________/______________   yr mo day

Page ____

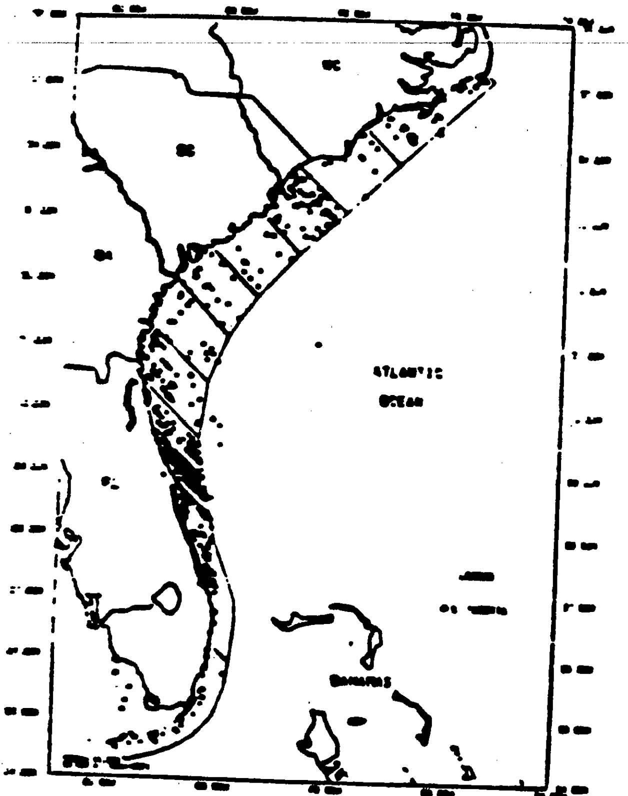
Transect# Time	# Animals	Species ID/ N,Y	Sighting Interval	Hiblty 1,2,3	B,U	Location Lat.	Long.	Observ #	NOTES: Behavior, Assoc.animals, vessels, size, heading, Gulfstream, environ. cond., basis of ID, shrimping, photos (roll/frame)	Sea State	Glare n,s,m,sv (R,L)	Sea T°	Turbdty s,m,t	Clouds c,hkn,oc & shadow	Visblty



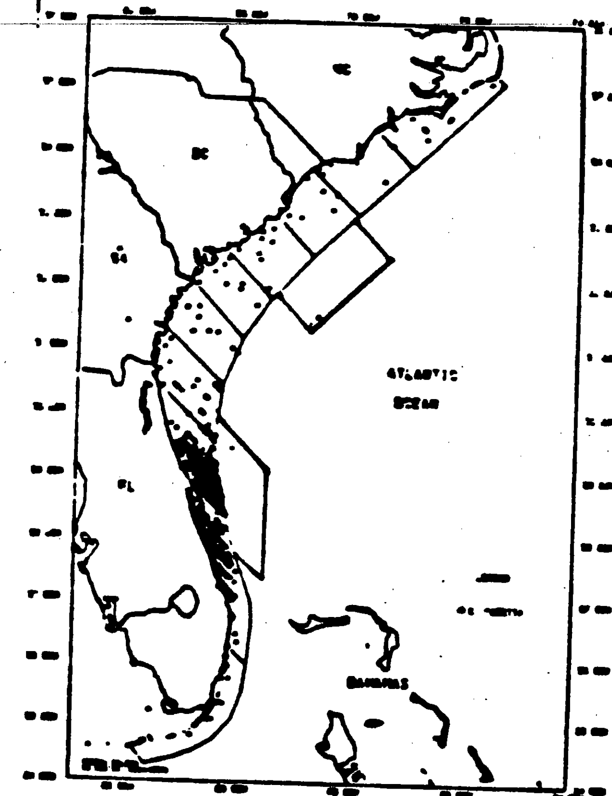
ALL C. CARETTA SIGHTED 82-83



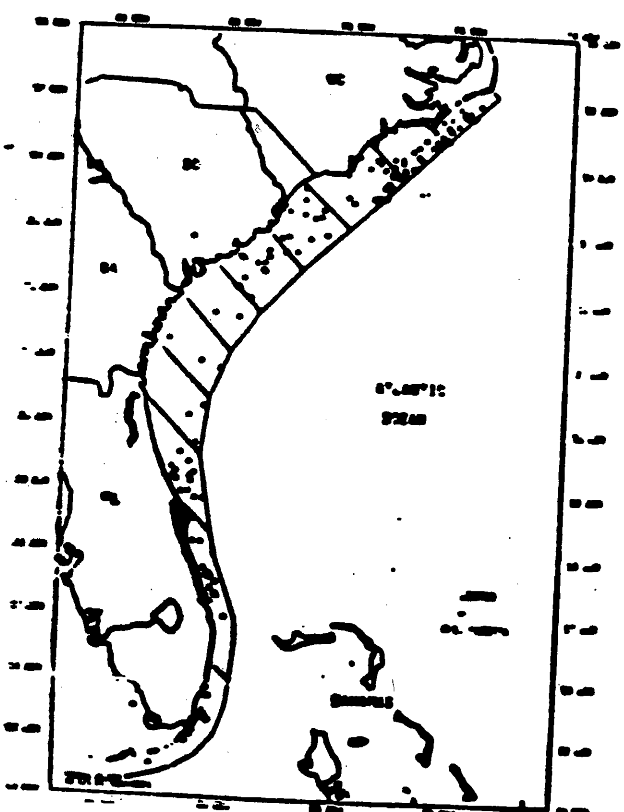
ALL D. CORIACEA SIGHTED 82-83



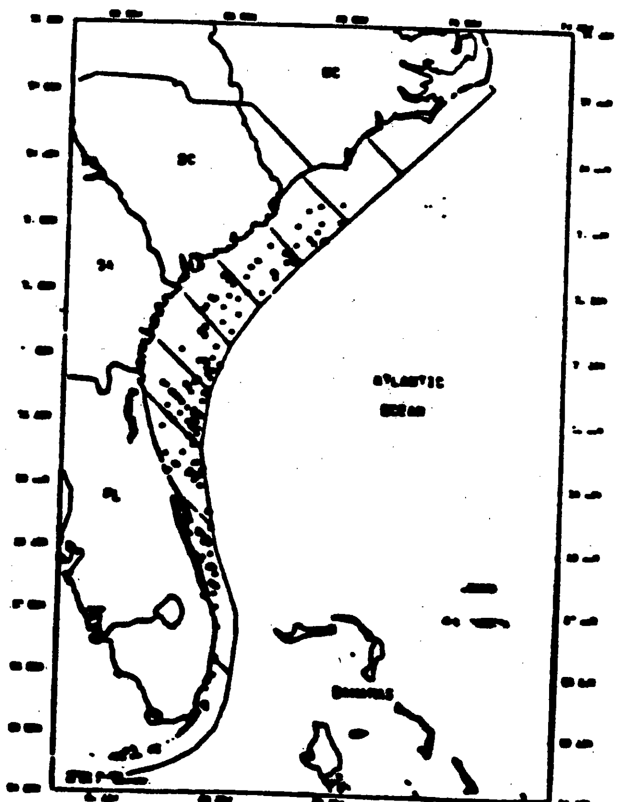
C. CARETTA SIGHTED SPRING 83



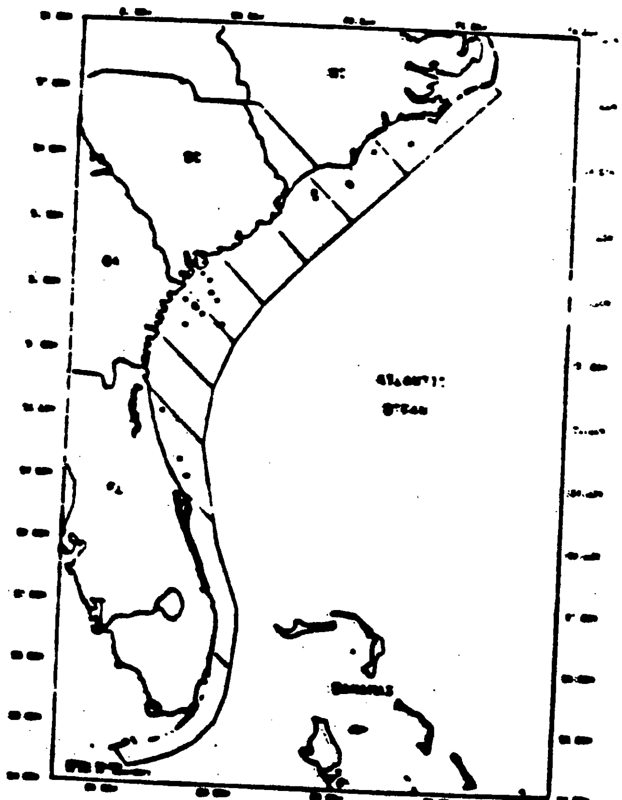
C. CARETTA SIGHTED SUMMER 83



C. CARETTA SIGHTED FALL 83



C. CARETTA SIGHTED WINTER 83



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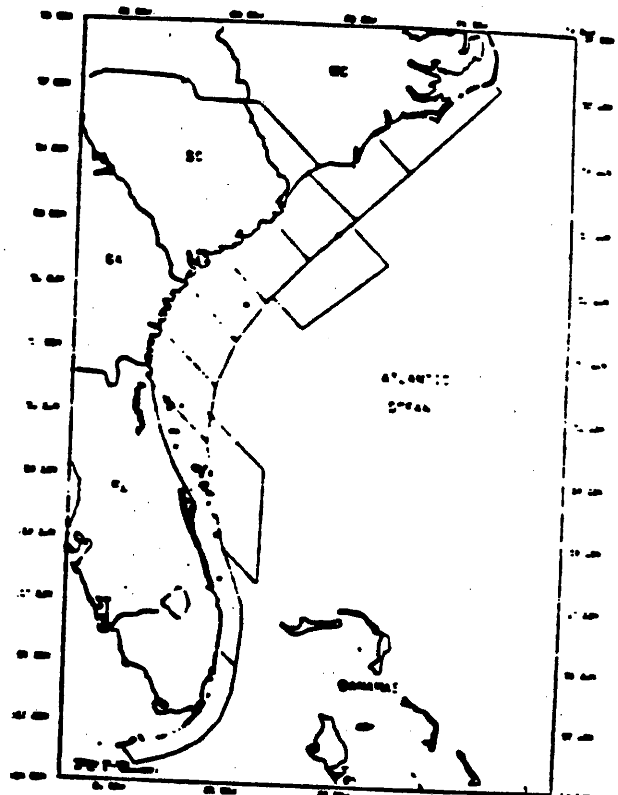

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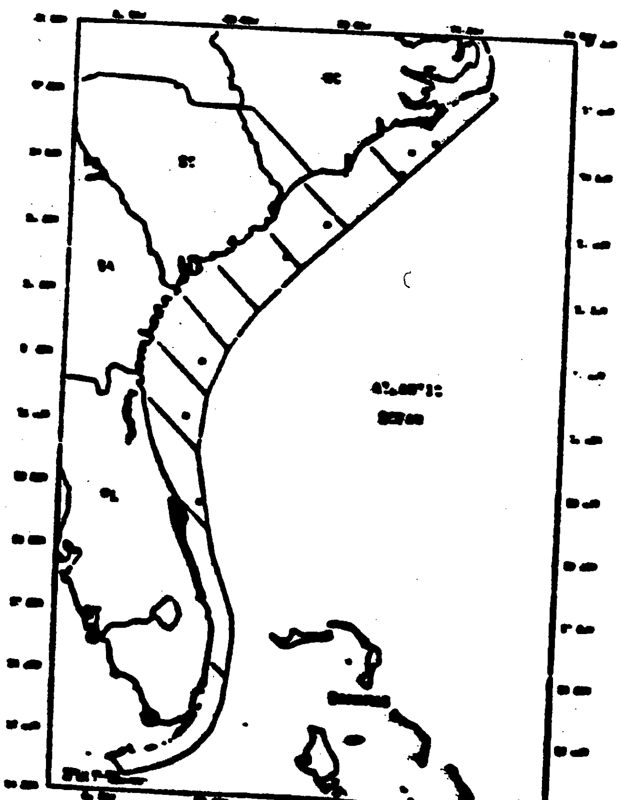

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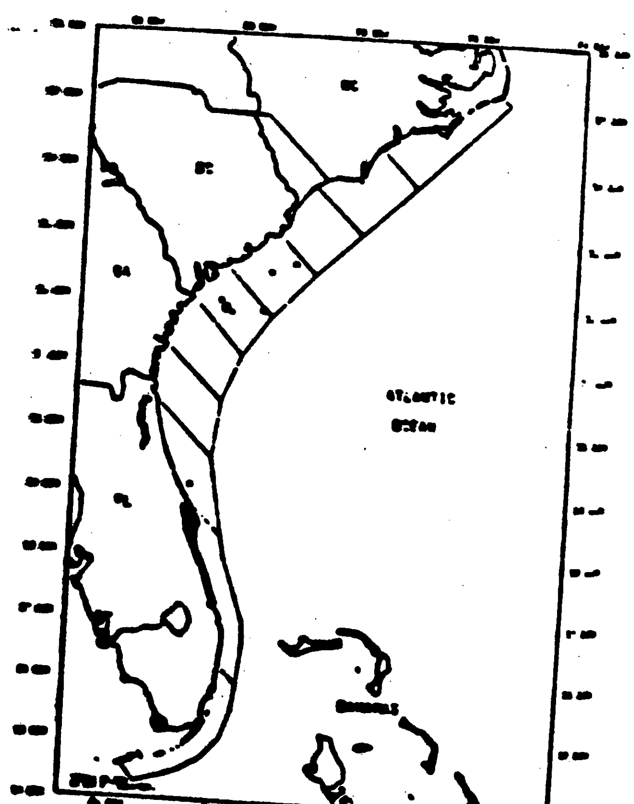

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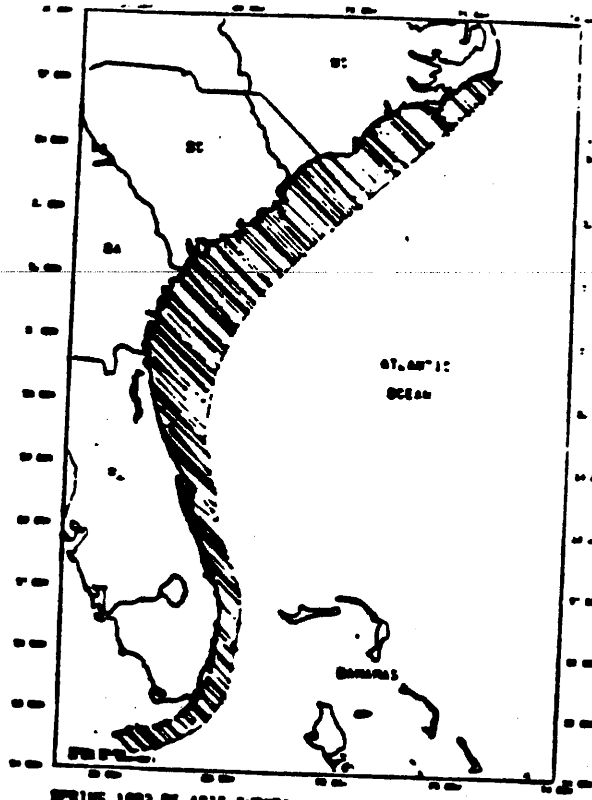
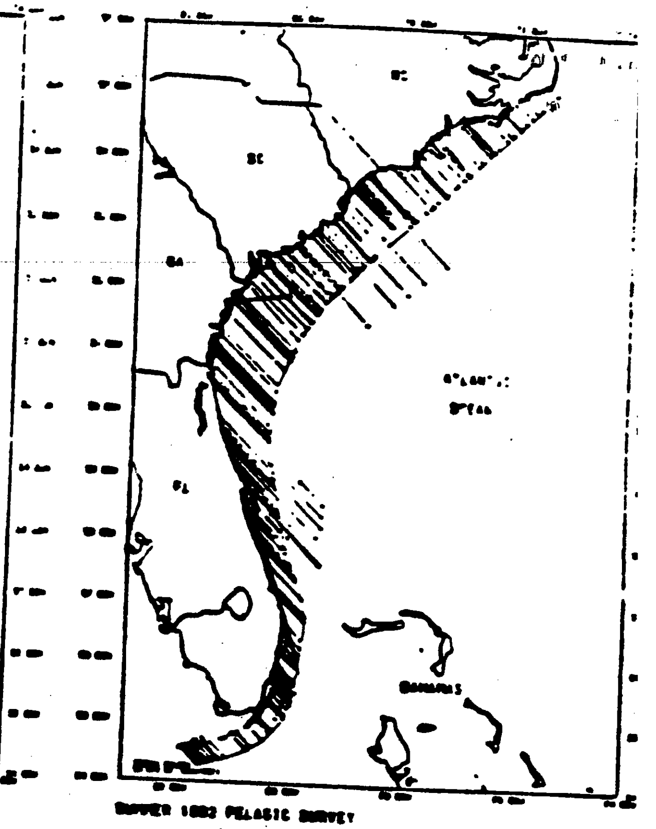
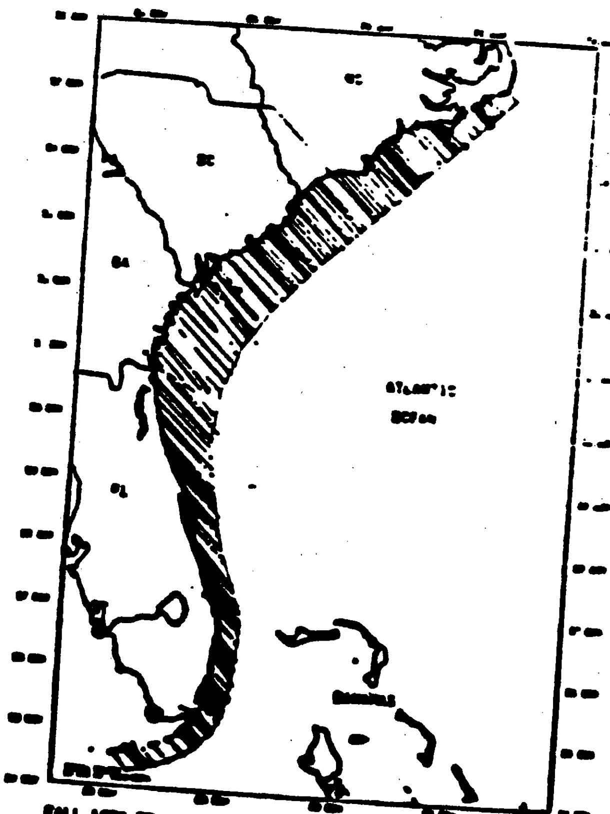


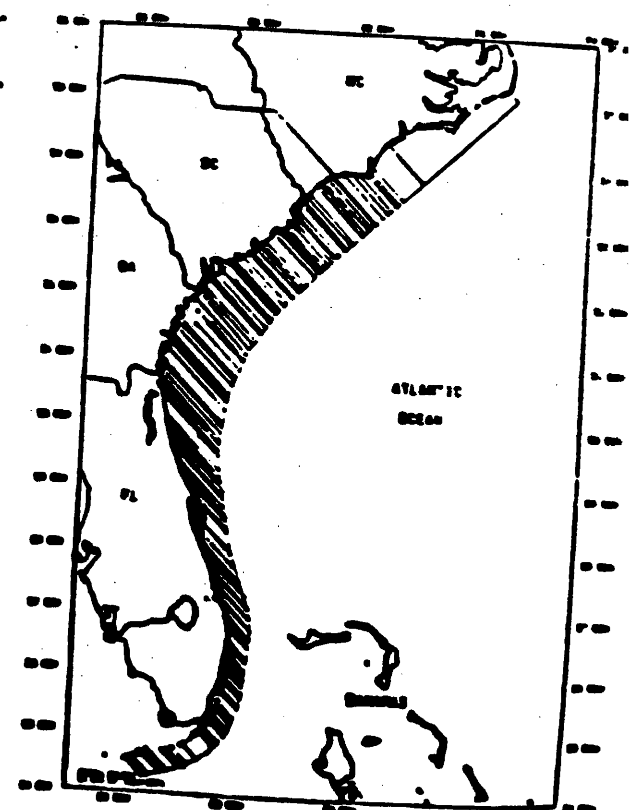
SPRING 1982 PELAGIC SURVEY



SUMMER 1982 PELAGIC SURVEY

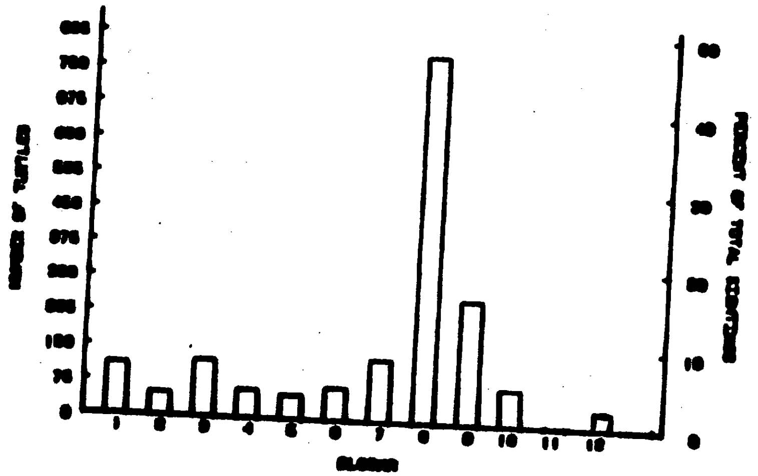


FALL 1982 PELAGIC SURVEY

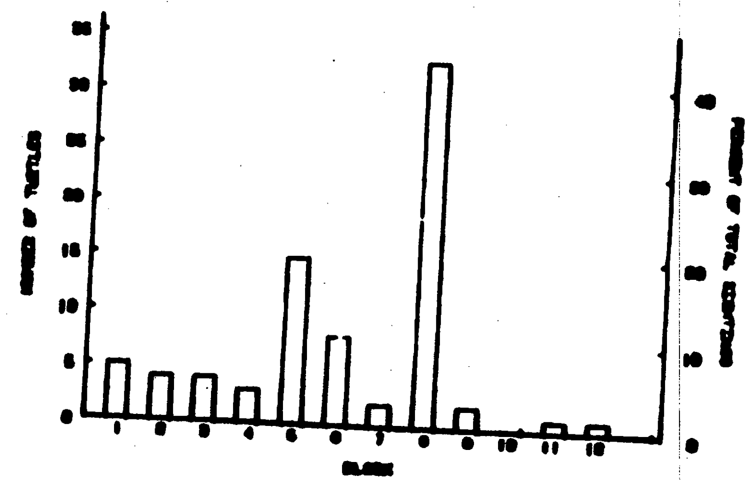


WINTER 1983 PELAGIC SURVEY

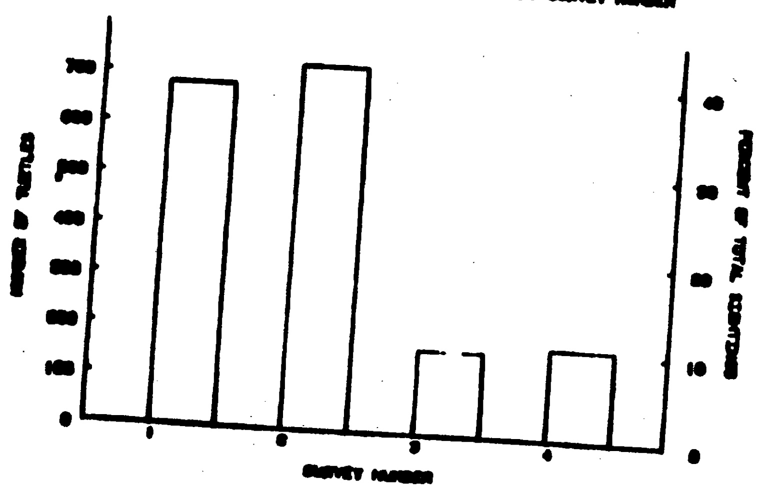
SIGHTINGS OF CARETTA CARETTA CLASSIFIED BY BLOCK



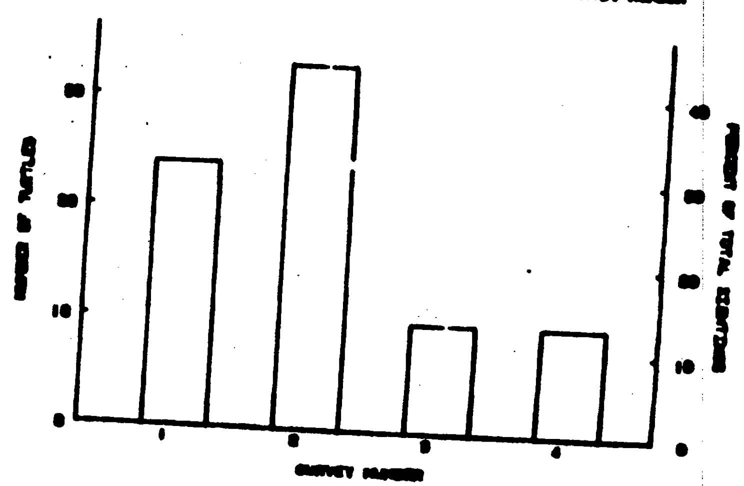
SIGHTINGS OF DERMOCHELYS CORIACEA BY BLOCK



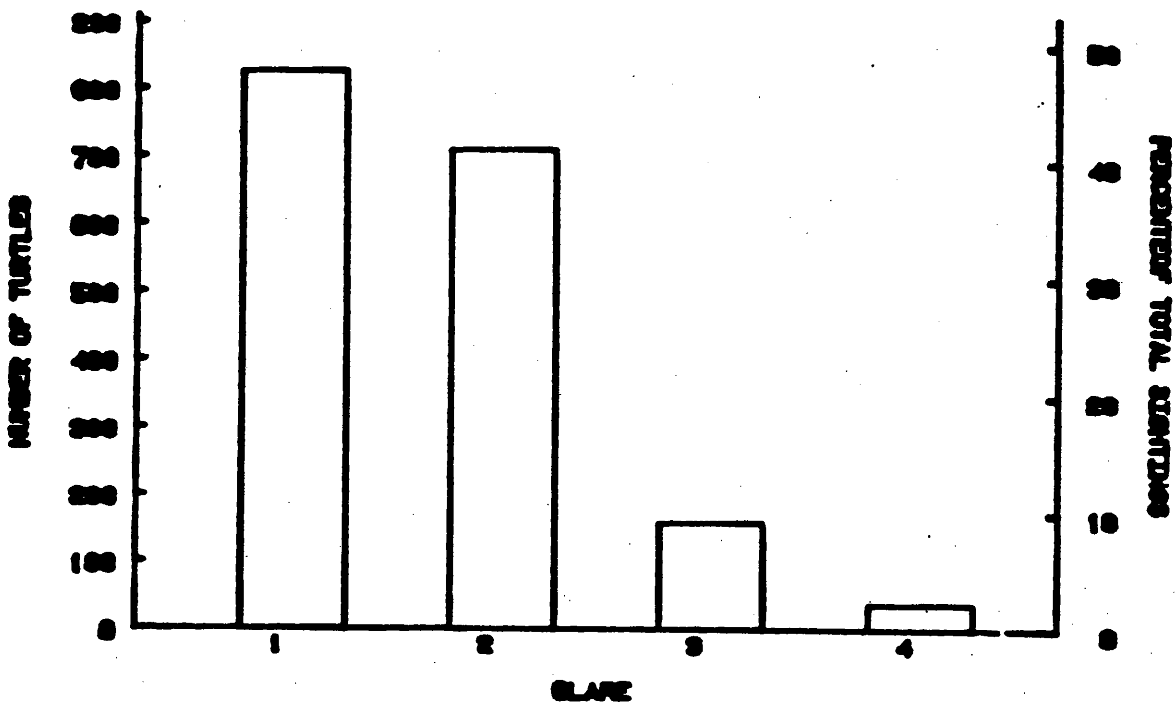
SIGHTINGS OF CARETTA CARETTA CLASSIFIED BY SURVEY NUMBER



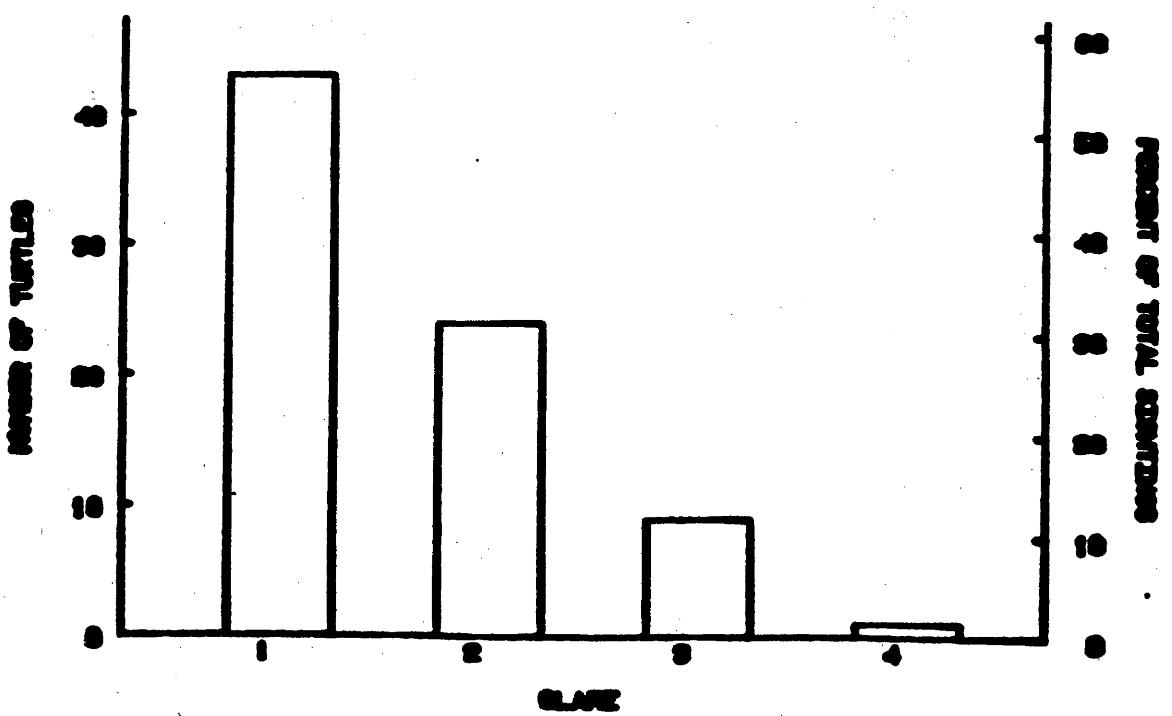
SIGHTINGS OF DERMOCHELYS CORIACEA CLASSIFIED BY SURVEY NUMBER



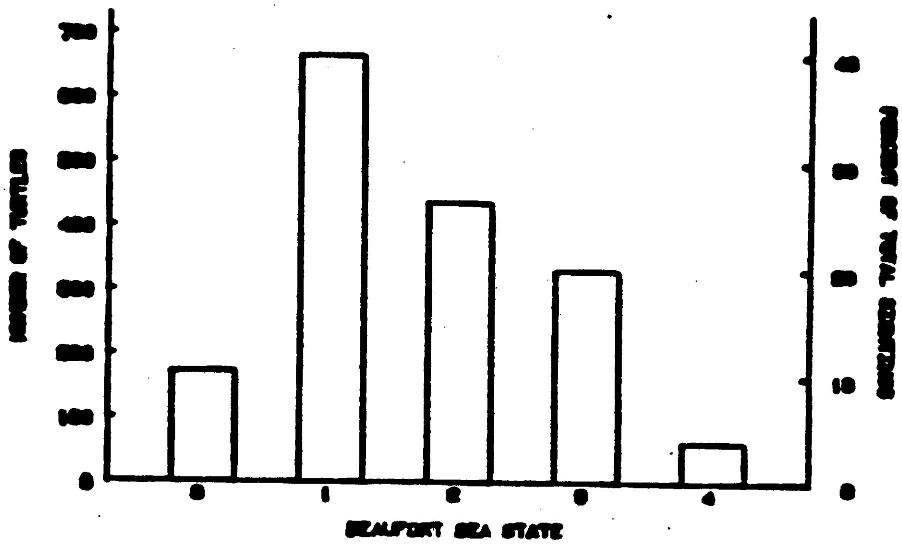
SIGHTINGS OF CARETTA CARETTA CLASSIFIED BY AMOUNT OF GLARE



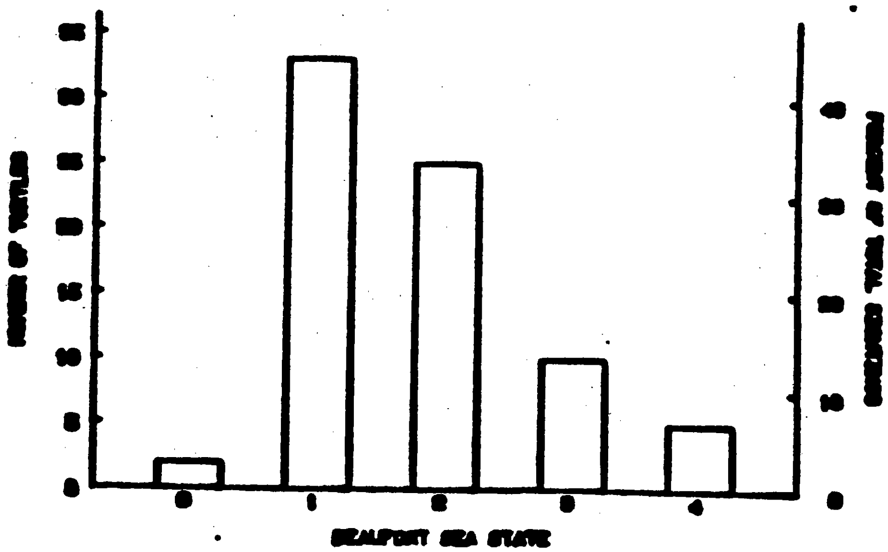
SIGHTINGS OF DERMOCHELYS CORIACEA CLASSIFIED BY AMOUNT OF GLARE



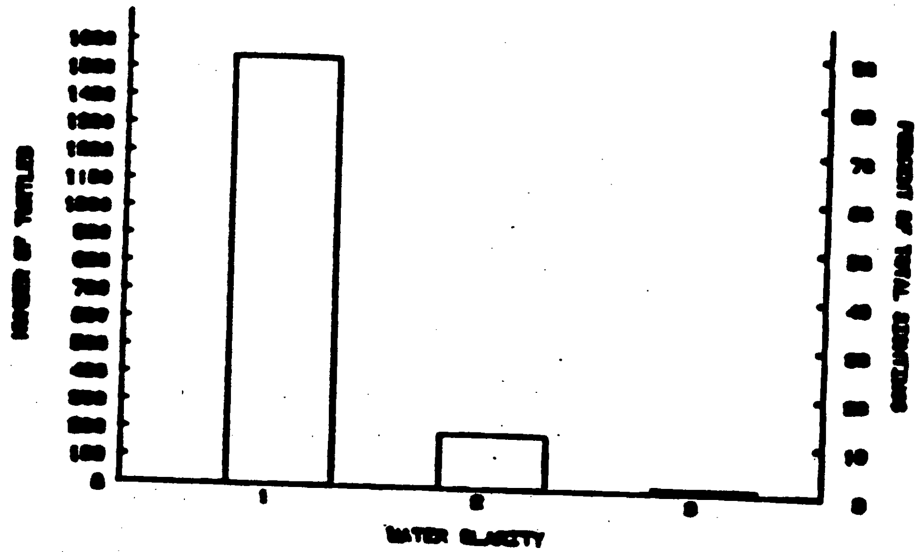
SIGHTINGS OF CARETTA CARETTA CLASSIFIED BY BEAUFORT SEA STATE



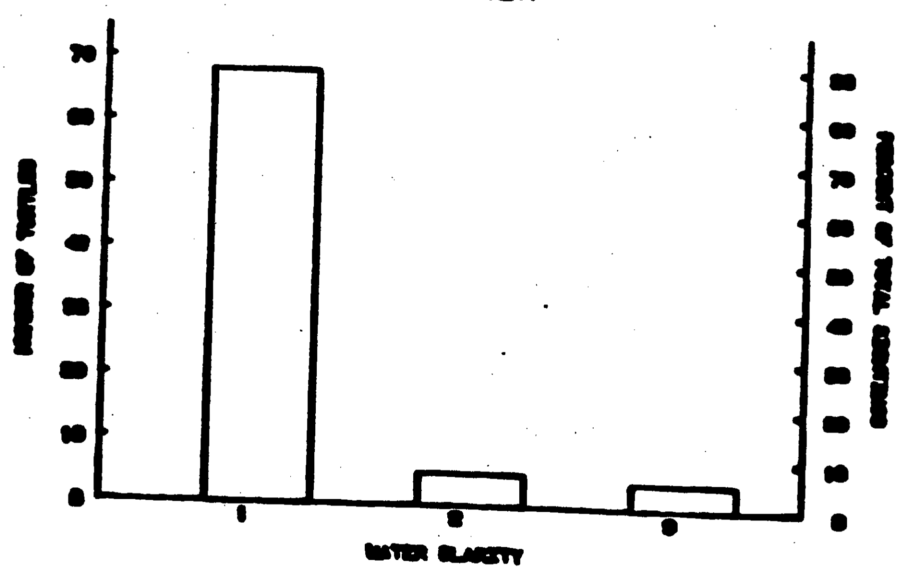
SIGHTINGS OF DERMOCHELYS CORIACEA CLASSIFIED BY BEAUFORT SEA STATE



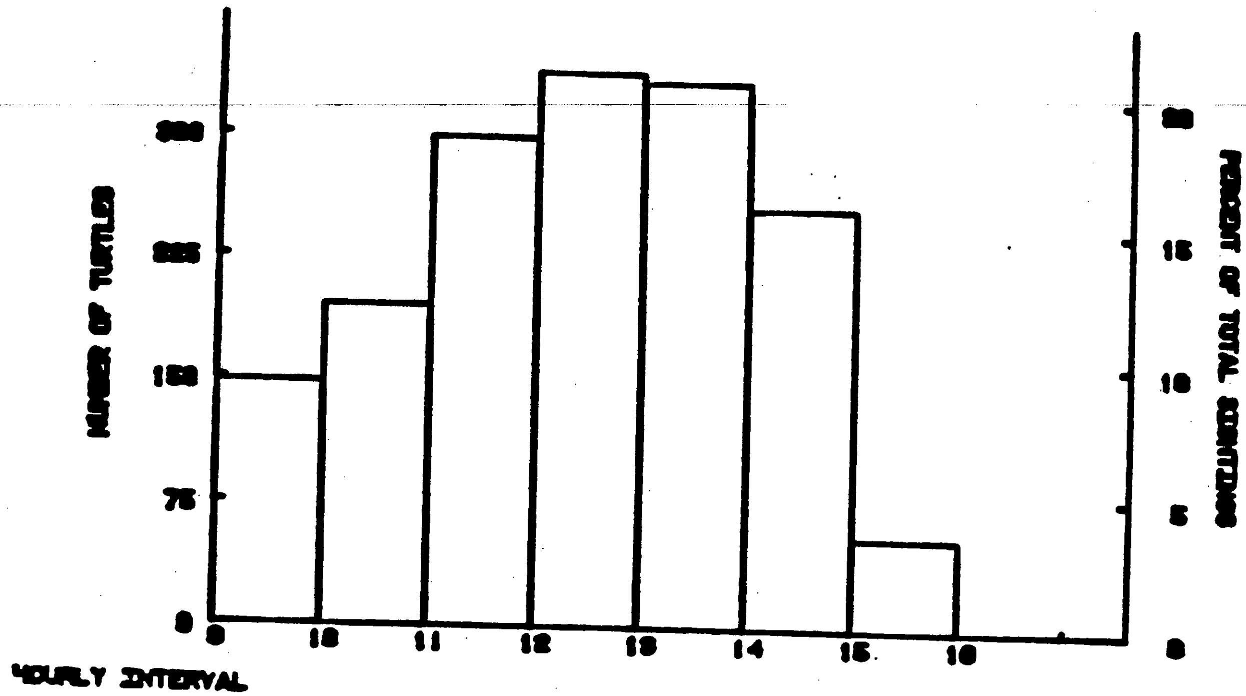
SIGHTINGS OF CARETTA CARETTA CLASSIFIED BY WATER CLARITY



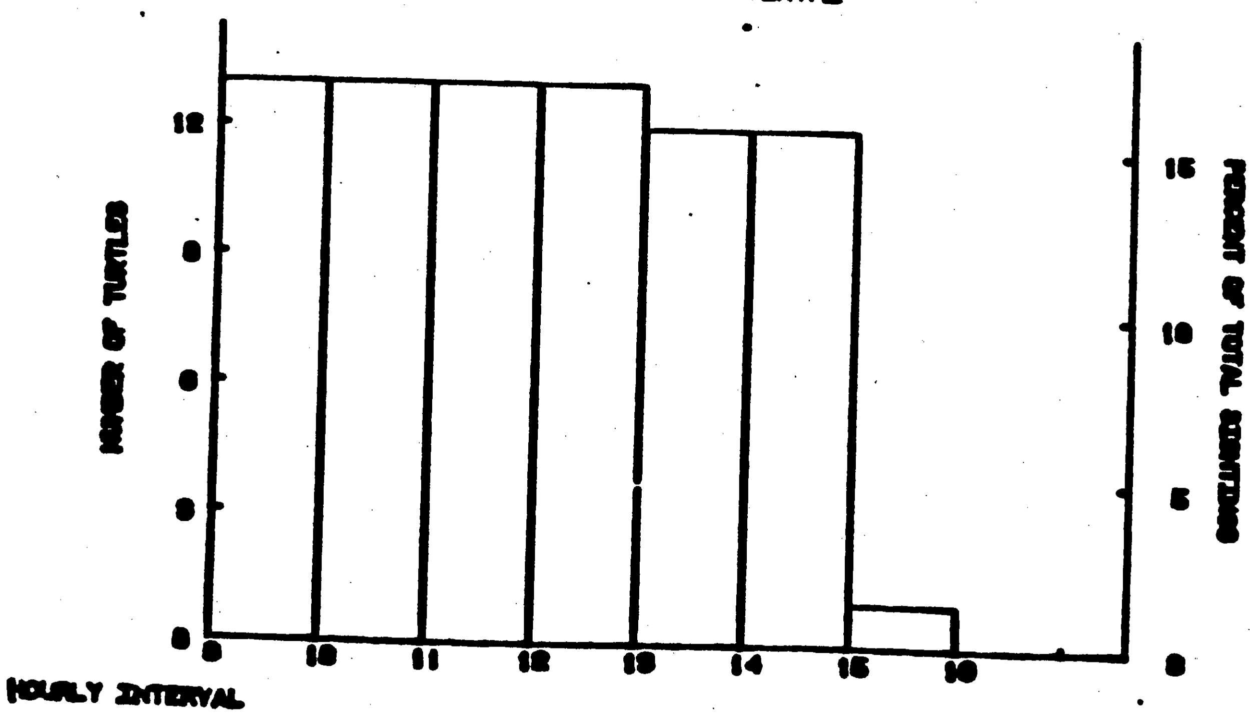
SIGHTINGS OF DERMOCHELYS CORIACEA CLASSIFIED BY WATER CLARITY

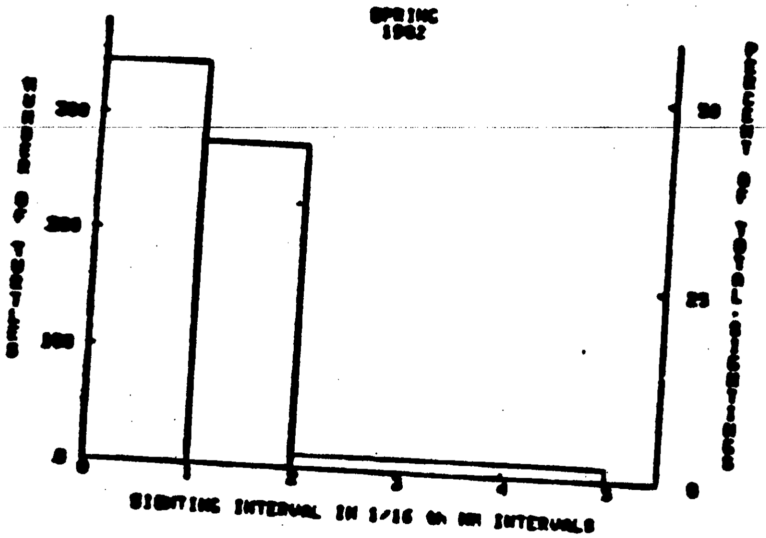


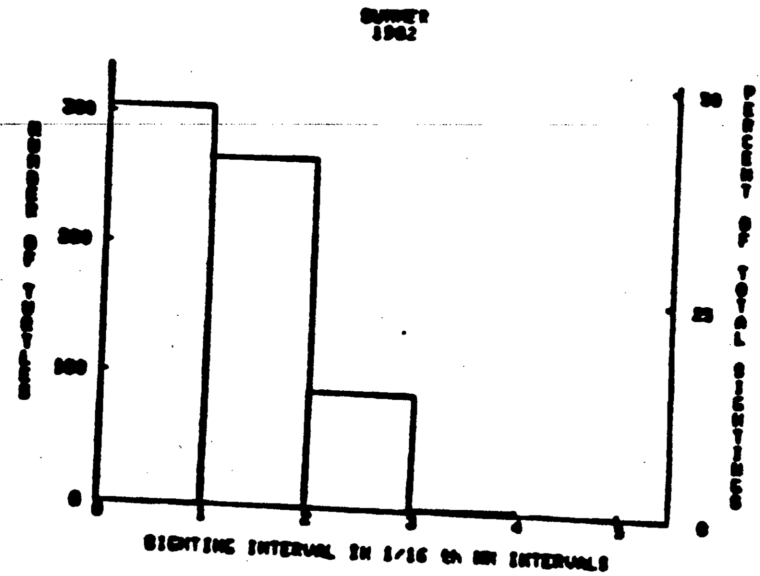
SIGHTINGS OF CARETTA CARETTA CLASSIFIED BY HOURLY INTERVAL

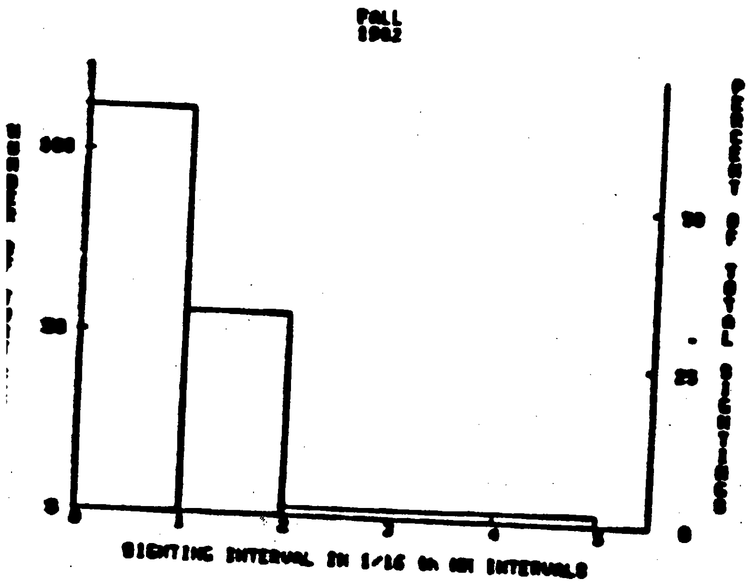


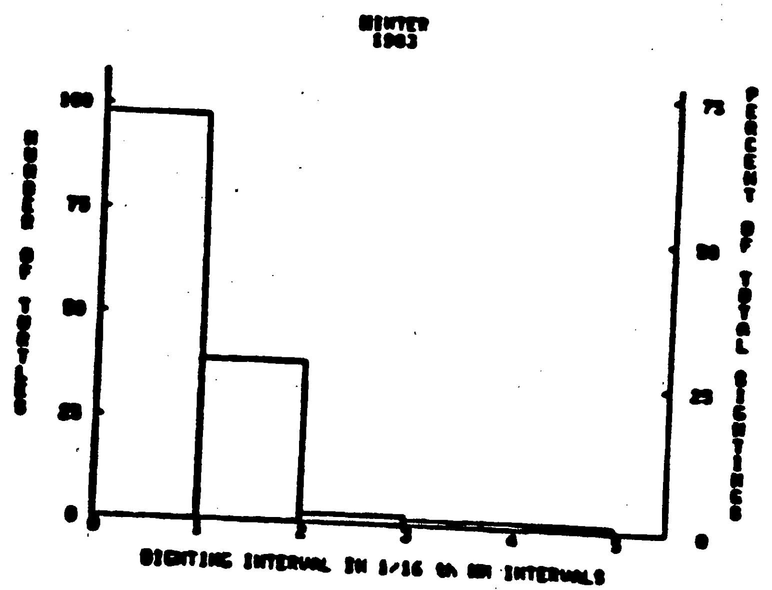
SIGHTINGS OF DERMOCHELYS CORIACEA CLASSIFIED BY HOURLY INTERVAL




SPRING
1982
SIGHTING INTERVAL IN 1/16 th NM INTERVALS


SUMMER
1982
PERCENT OF TOTAL SIGHTINGS
SIGHTING INTERVAL IN 1/16 th NM INTERVALS


FALL
1982
SIGHTING INTERVAL IN 1/16 th NM INTERVALS


WINTER
1983
PERCENT OF TOTAL SIGHTINGS
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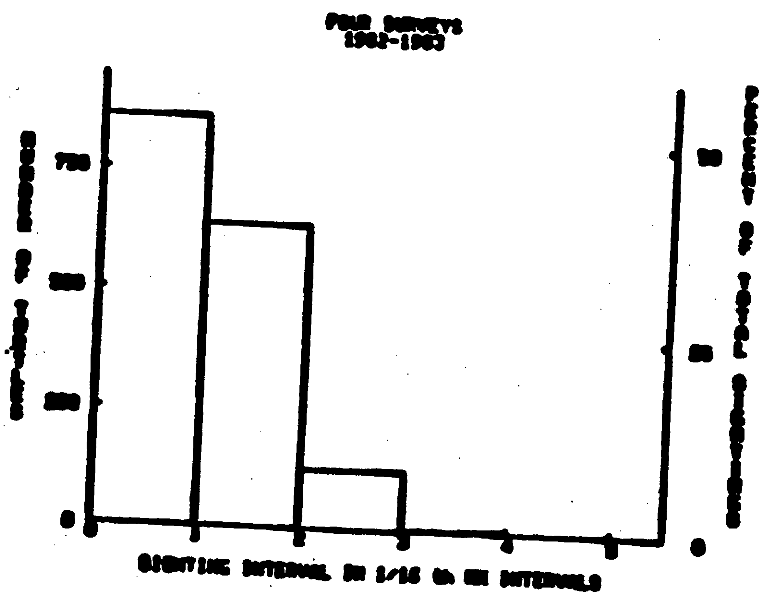
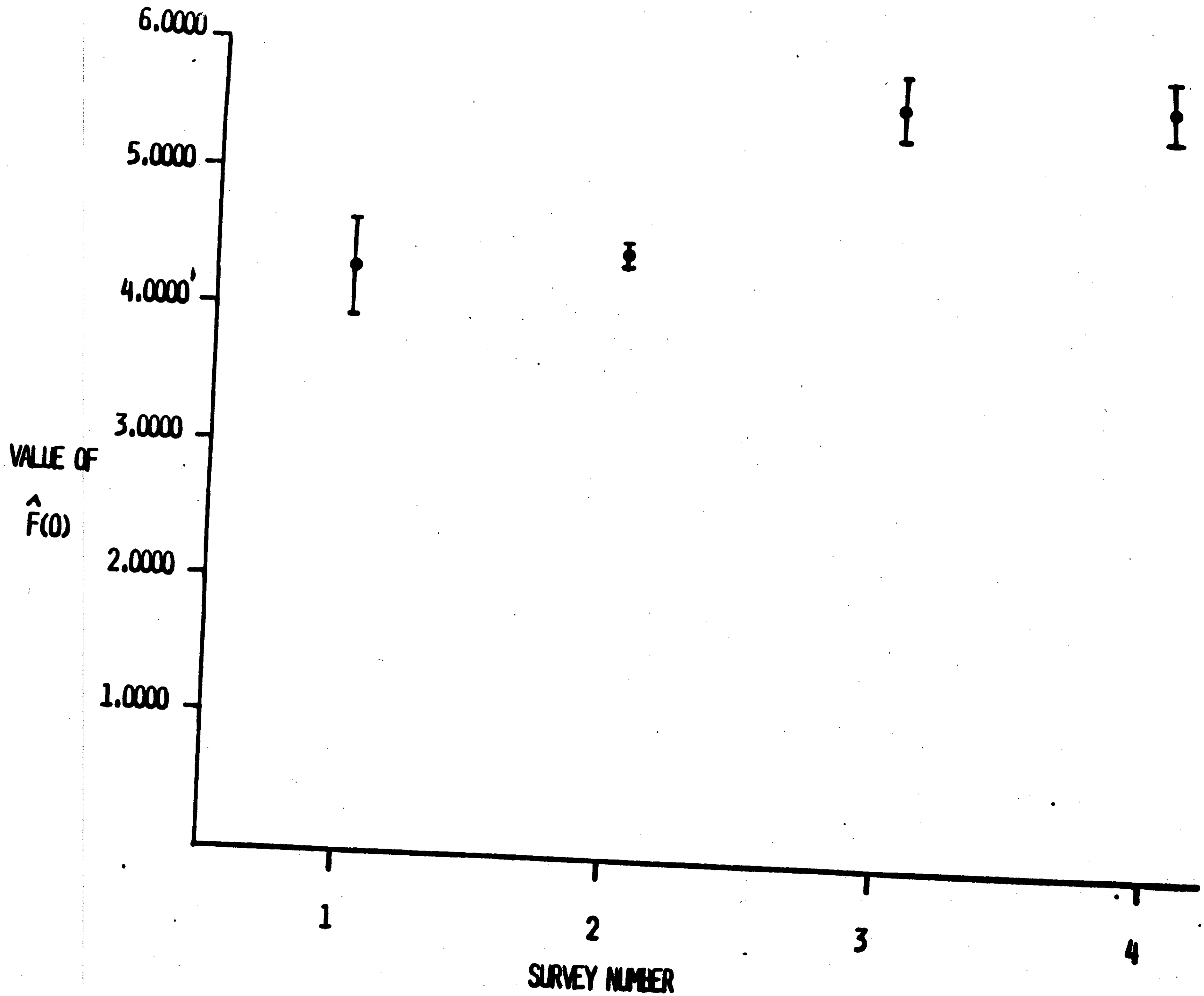

FOUR SURVEYS
1982-1983
SIGHTING INTERVAL IN 1/16 th NM INTERVALS



6.0000
5.0000
4.0000
3.0000
2.0000
1.0000
VALUE OF
$\hat{F}(0)$
1
2
3
4
SURVEY NUMBER